Developing cost-effective industry based techniques for monitoring puerulus settlement in all conditions: trials in southern and western Tasmania

Phase 1: Proof of concept

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In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

Contents

1. Non-technical summary

2011/020	**Developing cost-effective industry based techniques for monitoring puerulus settlement in all conditions: trials in southern and western Tasmania**

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Objectives:

1. To develop a puerulus collector that can:
   a) be used in deep water
   b) withstand adverse weather conditions as experienced in SW Tasmania
   c) be serviced by the fishing Industry
2. To evaluate the potential and cost-effectiveness of remote sampling (camera and satellite transmission)

Non-technical summary:

This is the final report for the first phase of this project in which prototypes of cost-effective techniques for monitoring puerulus settlement were designed and trialled.

Outcomes achieved to date

The outputs from this phase of the project have led to the following outcomes:

1. A puerulus collector design that:
   - Successfully collects and retains puerulus from deep water (>50m)
   - Can be easily and safely deployed, retrieved and serviced by vessels from the Tasmanian commercial lobster fleet during routine fishing operations
2. Southern rock lobster pueruli have been collected for the first time in deep water on the exposed southwest coast of Tasmania
3. A prototype camera system has been designed and constructed that:
   - Captures digital images on the seafloor at a pre-determined interval
   - Allows captured digital images to be viewed in real time on any computer with web access
   - Allows remote initiation of image capture, remote adjustment of the image capture rate, and remote software updating
4. Puerulus were observed in images captured by the camera system – highlighting its potential uses for long term monitoring at static sites such as puerulus settlement collectors

A review of the Tasmanian puerulus program undertaken in 2008 involving government, industry and an external review identified that the current puerulus collectors were all on the East Coast (with the exception of King Island); despite the southern and western regions supporting the largest catches in the fishery. The review identified as a priority to "investigate options for collection on the west coast using boat-based collection . . . and using commercial fleet to reduce cost of collection".

Through consultation with industry a design for a deep water collector was developed. Prototypes of this design were constructed and tested in aquaria with captured pueruli, on the seafloor adjacent to an existing inshore shallow collector site on the east coast of Tasmania, and in deep water on the south and southwest coasts of Tasmania. The prototype collectors were successfully deployed, retrieved and serviced by vessels in the commercial lobster fleet and vessel masters reported that the design facilitated safe and efficient handling on deck. The prototypes collected significantly more puerulus than adjacent routine collectors in deployments at the shallow site and collected puerulus for the first time on the deeper and more exposed southwest coast of Tasmania.

A collaboration involving IMAS, CSIRO and Scielex has been successful in developing a remote camera system capable of capturing images on the seafloor at a pre-determined interval. Images are transmitted in real time using the 4G network to a web server from where they can be viewed on any computer with internet access. The system is comprised of submerged cameras and lights suspended from a surface buoy which houses a battery, solar charging system, single board computer, wireless 4G modem, analogue camera server, analogue to digital converter and relays. The computer can be accessed remotely to adjust capture intervals, spontaneously capture images, and update or troubleshoot software.

In field tests the camera system delivered discernable images of southern rock lobster puerulus. Consequently, this system can be applied to monitor puerulus settlement and post-settlement behaviour at fine temporal scales, allowing assessment of the representativeness of monthly serviced settlement collectors.

Both the deep water collector and the remote camera system offer opportunities for cost-effective monitoring of puerulus and meet the objectives of the first phase of this project. Under the second and third phases, use of these systems can improve understanding of the spatial resolution of settlement, provide greater certainty for managers and industry regarding the representativeness of the current (shallow) collectors, and aid in refining the relationship between observed puerulus settlement and future predicted catches for the fishery.

Keywords:
Puerulus, larval settlement, deep water, lobster fisheries, industry monitoring, remote camera

2. Acknowledgements

The project was jointly funded by the Fisheries Research and Development Corporation (FRDC project 2011/020), and the Institute for Marine and Antarctic Studies, University of Tasmania. We acknowledge the support of the Tasmanian rock lobster commercial fishing industry in the formulation of prototype deep water collector designs, and in the deployment and servicing of puerulus collectors on the south and southwest coasts of Tasmania. In particular, we wish to thank Rodney Treloggen, Kent Way and Brendon Taylor for their direct involvement in this project. We also wish to acknowledge Scielex Pty. Ltd. for their contributions to the design of the remote camera system, and in particular Gerald Verdouw.

3. Background

The project was developed to assist in the sustainable management of the southern rock lobster fishery in Tasmania. It addresses FRDC's strategic challenge to ensure that the Australian community derives optimal economic, environmental and social benefits from its fishery and aquaculture resources and addresses the themes of ecological sustainable development and climate change. This is achieved through an improved understanding of recruitment to the resource and in development of cost-effective monitoring systems that involve and engage the fishing industry. The project also addresses a priority from a review of the puerulus program undertaken in 2008. This review that involved government, industry and an external review identified that the current collectors were all on the East Coast with the exception of King Island. The review identified as a priority "investigate options for collection on the west coast using boat-based collection . . . and using commercial fleet to reduce cost of collection". Particular emphasis was given to the southern and western regions as these support the largest catches from the fishery.

A priority from a review of the puerulus program involving government, industry and an external reviewer was:

1. **Recruitment**: Poor recruitment on the east coast of Tasmania has resulted in declining effort in this region which was re-directed to the southern and western regions until a decrease in the quota was implemented. A recent report detailing the correlation between puerulus settlement and oceanographic conditions on the east coast of Tasmania has aided both industry and managers in understanding the current and potentially future outlook for the fishery in this region. Unfortunately similar information does not exist for the southern and western regions of the fishery despite these regions being the major lobster fishing regions in Tasmania. Previous trials at deploying puerulus collectors in southern and western regions of Tasmania have been unsuccessful due to the rough weather and sea conditions. These trials had been in shallow water regions and in close proximity to boat launching ramps so that they could be serviced by Departmental staff at regular (monthly) intervals. This proposed project will design a deeper-water collector that can be serviced by the fishing industry. The executive officer and president of the TRLFA see the need for information on settlement in this region and will ensure that industry partake in the workshop to determine an appropriate design and in trialling the collectors during this initial phase of the project. The manager of the Tasmanian rock lobster fishery is also supportive of the project for providing longer-term trends in the settlement of puerulus in this important area of the fishery. Support letters were attached to the pre-proposal. The WA lobster fishing industry has also expressed interest in understanding if there could be settlement in deeper-waters in Western Australia and a letter of support for the project was provided by the Western Australian Department of Fisheries. Using the WA collectors, they were unable to sample in deeper water due to weather conditions and thus they identified that specific collectors would be required and they are keen to trial the collectors developed in this project. In addition to developing a sampling device, the project will also determine if there are depth limits/regions where puerulus settle. Importantly, with the warming of shallow coastal waters, is there the potential for puerulus to settle in deeper waters. Thus a decline in current collectors could be due to lower recruitment from the ocean and/or a change in settlement patterns to increased settlement in waters deeper than currently monitored (<10m).

2. **Cost-effectiveness**: Currently the puerulus monitoring program is an expensive component of the overall research budget as it involves a minimum of three divers and several days each month in the field. The project will also compare the deeper-water collectors against the shallow water collectors and it might prove more cost-effective to use either the industry to service collectors in the future or use collectors that do not require diving. The project will also investigate the potential of an underwater camera system to monitor settlement. During the project we will have access to an underwater camera and transmission system, being developed for other applications by CSIRO ICT Centre that will relay pictures to the IMAS laboratory. We will evaluate this technology for reducing costs (e.g. minimising the number of visits to the field) and for improving

our knowledge of puerulus settlement and thus recruitment to the fishery. As photos will be taken over 24 hours each day, we will also be able to investigate puerulus settlement behaviour. For example, do puerulus arrive in groups or individually? What is the retention time on a collector? How reliable are monthly puerulus counts as a measure of monthly activity on a collector? This information is expected to aid in refining the relationship between observed puerulus settlement and future predicted catches for the fishery.

4. Need

Rock lobster fisheries throughout southern Australia are in decline with resultant direct and indirect losses of hundreds of millions of dollars annually. While the cause for the decline is uncertain, observed declines in the recruitment of larvae is of concern in western and eastern Australia. In Australia, larval (puerulus) collectors have been established in shallow water regions where they are serviced by divers (SA, Tas & Vic) and from dinghies (WA). By requiring servicing by department staff, and particularly by dive teams, collectors are expensive to service and thus limited in their regional distribution to a few sites. For southern rock lobster there has been concern over how well the observed larval settlement represents the entire fishery as sampling sites are few and the majority of catch is from deeper reefs. To improve our understanding of the relationship between recruitment, future catches and short and long term recruitment trends, there is a need to improve spatial (region and depth) coverage. Previous attempts to deploy puerulus collectors in shallow regions in southern and western Tasmania, where over 60% of the catch is obtained, have failed due to weather conditions. To-date there has been no attempt to trial deeper water collectors.

This proposal requests funding for phase 1, the development and trial of deepwater collectors, of a 3 phase project with the ultimate aim to develop cost-effective collectors that can withstand all weather conditions, can be serviced in deeper water and can be serviced by the fishing industry throughout southern Australia.

5. Objectives

1. To develop a puerulus collector that can:
    a) used in deep water
    b) withstand adverse weather conditions as experienced in SW Tasmania
    c) be serviced by the fishing Industry

2. To evaluate the potential and cost-effectiveness of remote sampling (camera and satellite transmission)

6. Methods

In this first phase of the project, the aim was to demonstrate proof-of-concept by developing prototypes of a deep water collector and a puerulus camera system that meet the objectives, and hence warrant funding of the second and third phases, of the project.

6.1 Development of a deep water collector

Puerulus collectors generally incorporate a settlement strata (which provides a habitat desirable for settling puerulus), a collector base on which to mount settlement strata on the seafloor, and a means of retrieval such as buoy-line and surface buoy.

6.1.1 Selection of a collector substrate

In order to inform the choice of strata that are likely to attract and retain *Jasus edwardsii* pueruli, and to assist in the selection of representative sampling sites, a review of the literature on puerulus settlement and on the use of artificial substrata for collection of puerulus was conducted. On the basis of the review, four potential strata were selected for collector trials, and appropriate housings were constructed to contain and protect the strata.

The relative performance of these strata was estimated from deployments of strata at existing shallow water puerulus collection sites and from habitat preference trials in aquaria using captured puerulus. Collectors in the field trials were cleared of puerulus monthly. Strata in the aquarium trials were serviced daily by removing all puerulus from the aquarium and then re-positioning and re-introducing puerulus. The two strata that attracted and retained the most pueruli were used for deep water deployments.

6.1.2 Calibration against inshore collectors

Puerulus settlement has been monitored for over two decades at inshore sites on the south east and east coasts of Tasmania using booth crevice collectors (Booth and Tarring 1986; Gardner, Frusher *et al.* 2001). Retrieval of collectors at these sites is by diver and entails "bagging" the collectors on the seafloor to eliminate losses of puerulus by flushing on retrieval. As it would be impractical to bag deep water collectors prior to hauling, strata housings were constructed to include a sieve to retain puerulus flushed from the strata during retrieval.

Given that a smaller entrance area (due to the sieve) is likely to influence settlement, and that attraction and retention of pueruli is likely to vary across strata types, the deep water strata and housings were deployed adjacent to an existing shallow water puerulus monitoring site. Three of each of the four trial strata were installed in deep water collector housings and deployed in 7m of water in Waubs Bay at Bicheno on the east coast of Tasmania from June 2012 to December 2012. Strata types were allocated randomly to a collector grid and strata were retrieved and serviced monthly as part of the routine servicing of existing long-term collectors to enable comparison of puerulus settlement rates from deep water collectors with that recorded in shallow water collectors. Unlike the bagging of routine collectors on retrieval, the deep water trial collectors were not bagged on retrieval and relied on the sieve in the stratum housing to retain puerulus flushed from the strata during hauling from the seafloor.

Differences in collection rates between collector types were tested for significance using a t-test assuming unequal variances.

6.1.3 Industry workshop

Consultation with industry was required to ensure that the design of the deep water collector base and retrieval system could be serviced by vessels from the commercial fleet. Consequently, a workshop was convened on the 28th February 2012 and was attended by experienced rock lobster fishers, representatives from Tasmanian peak fishing industry organisations, CSIRO and IMAS. A prototype deep water collector was designed, and a gear configuration for hauling and retrieving was developed, on the basis of the conclusions of the workshop.

6.1.4 Inshore deployment trials

The prototype deep water collector was deployed and retrieved from a commercial vessel in local inshore waters to ensure that it was within the capacity of the line haulers and pot lifters. The prototype was deployed and hauled on 5 separate occasions from 13m water depth, and the orientation of the collector on the seafloor was inspected by a diver after each deployment.

6.1.5 Deployment on the south and south west coasts of Tasmania

Twenty four deep water collectors were constructed, galvanised and deployed on the south and southwest coasts of Tasmania in October 2012. They were deployed at 4 sites, each with 6 collectors. Each site hosted two strings of 3 collectors, and 3 replicates of each stratum were allocated randomly to across the two strings at each site. Two sites were on the south coast to the east of De Witt Island, and two sites were on the southwest coast off the Pyramids (fig.1) (Table 1). Collectors were deployed on soft sediment and each string consists of a ground-line (hosting 3 pots on snoods) with buoy-lines and current buoys at both ends.

Fishers servicing the deep water collectors were issued a service kit and log sheets (appendix 6) and servicing was accomplished around early December 2012 and again in early February 2013 after a soak times of 6 to 8 weeks. Servicing involved retrieval of collector strings; removal of the strata; checking and recording the presence of puerulus or other animals in the strata and sieve; preservation of animals; re-assembly of the strata; and re-deployment of the collector strings.

Table 1: Depths at deep water collector deployment sites.

Site code	Site description	Depths (m)	Seafloor	Number of collectors
S1	South shallow	57-62	sand	6 (2 strings)
S2	South deep	93-95	sand	6 (2 strings)
SW1	Southwest shallow	62-68	sand	6 (2 strings)
SW2	Southwest deep	97-102	sand	6 (2 strings)

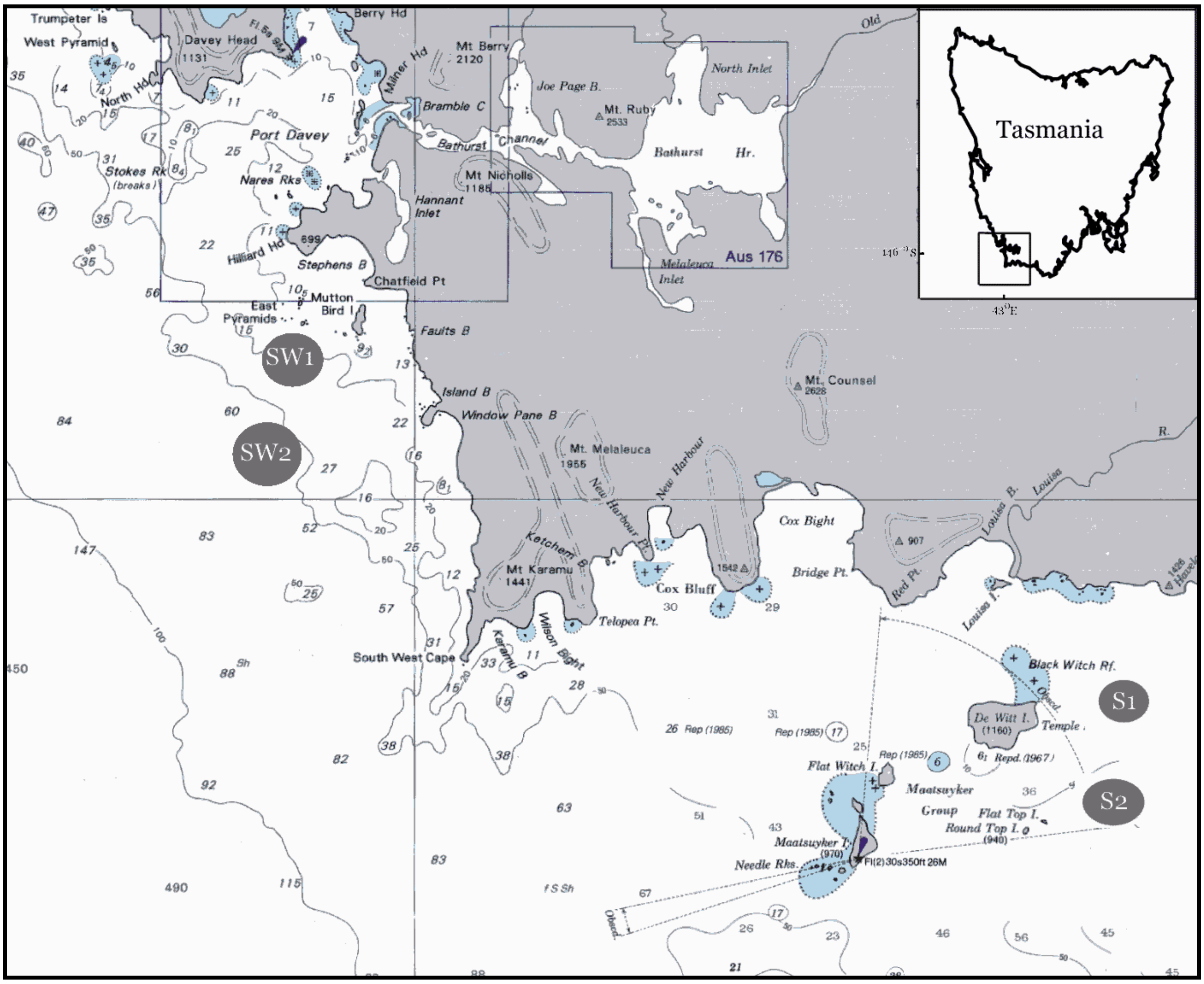

Figure 1: Map showing the areas on the south (S1 and S2) the south west (SW1 and SW2) coasts of Tasmania where prototype deep water puerulus collectors were deployed.

6.2 Development of puerulus monitoring camera system

Under this project, IMAS, CSIRO Intelligent Sensing and Systems Laboratory (ISSL) and Scielex P/L (environmental electronics) have collaborated to develop a camera system capable of capturing images at predetermined intervals of puerulus on collectors on the seafloor, such that images can be viewed remotely and in real time. A prototype camera system was constructed and underwent extensive desktop trials at CSIRO. Underwater trials were conducted in December 2012 to examine the extent to which puerulus could be detected on collector strata using this camera system.

7. Results/discussion

7.1 Development of a deep water puerulus collector

7.1.1 Selection of a collector substrate

On the basis of the review of the literature on puerulus settlement and collection using artificial strata (appendix 3), and given the presence of adult *Jasus edwardsii* on reefs in deeper offshore waters, it is likely that pueruli settle into these depths. Also on the basis of this review, four collector strata that were likely to be suitable for collection of *J. edwardsii* were selected for deep water trials.

Booth crevice collectors were chosen because they have a proven track record of collecting *J. edwardsii* in shallow Tasmanian waters and have generated a long time series of settlement data (Booth and Tarring 1986; Cohen and Gardner 2007) (Fig. 1a). Mesh bags were chosen because they are inexpensive, easy to service, and are likely to minimise loss of puerulus on retrieval due to the complex nature of the habitat they provide (Fig. 1b). Grids of fibreglass reinforced plastic (FRP) mesh were chosen because they are inexpensive, rigid, and easy to service (Fig. 1c); and Hebel blocks were chosen due to their proven ability to attract settlers and their rigid and coarse surface (Fig.1d).

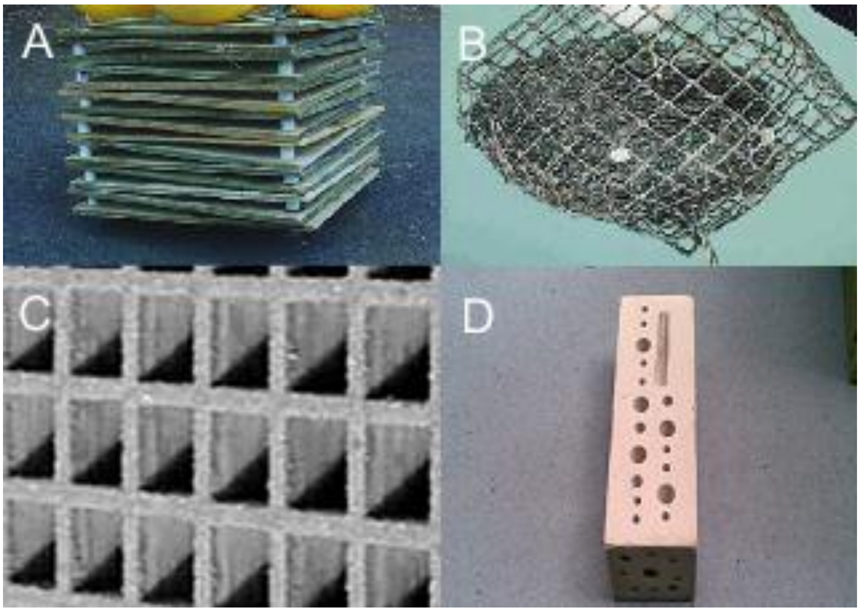

Figure 2: Settlement strata trialled in aquaria and at an existing shallow water puerulus collection site.

The results from aquarium and field habitat preference trials are shown in Table 2. Aquarium habitat preference trials showed that if given a choice of habitats, captured puerulus were more likely to inhabit crevice strata. Unfortunately, FRP mesh strata were not available for aquaria trials. However, in a single aquarium trial with crevice and FRP strata, puerulus were approximately evenly distributed between the two strata (10 and 12 puerulus respectively). The field habitat trials also showed that puerulus were more likely to settle on crevice and FRP mesh strata. Consequently, crevice and FRP mesh strata were selected for field trials in deep water.

Table 2: Monthly mean of the number of settled puerulus per collector for each stratum type in field trials; and daily mean of the number of captured puerulus per collector for each stratum type in aquarium trials. Standard errors are in brackets.

Strata	Field		Aquarium	
	Mean number of pueruli	Number of trials	Mean number of pueruli	Number of trials
Crevice	14.3 (1.8)	4	14.5 (1.8)	4
FRP	15.7 (2.9)	4		
Hebel	2 (1.2)	4	0.7 (0.3)	4
Mesh	1 (0.58)	4	5.3 (0.3)	4

7.1.2 Comparison with inshore collectors

Puerulus settled on the trial deep water collectors (crevice and the FRP strata) in every month of their deployment at the Waubs Bay (Fig. 3). Collection rates in either of the strata used in the trial collectors were higher in every month than collection rates at the adjacent routine monitoring site (Table 3) (with the exception of the FRP stratum in December). Deep water trial collectors recorded significantly higher numbers of settlers across the season (June 2012 to December 2012), however monthly differences were only significant in August and September where seasonal settlement was highest Table 3).

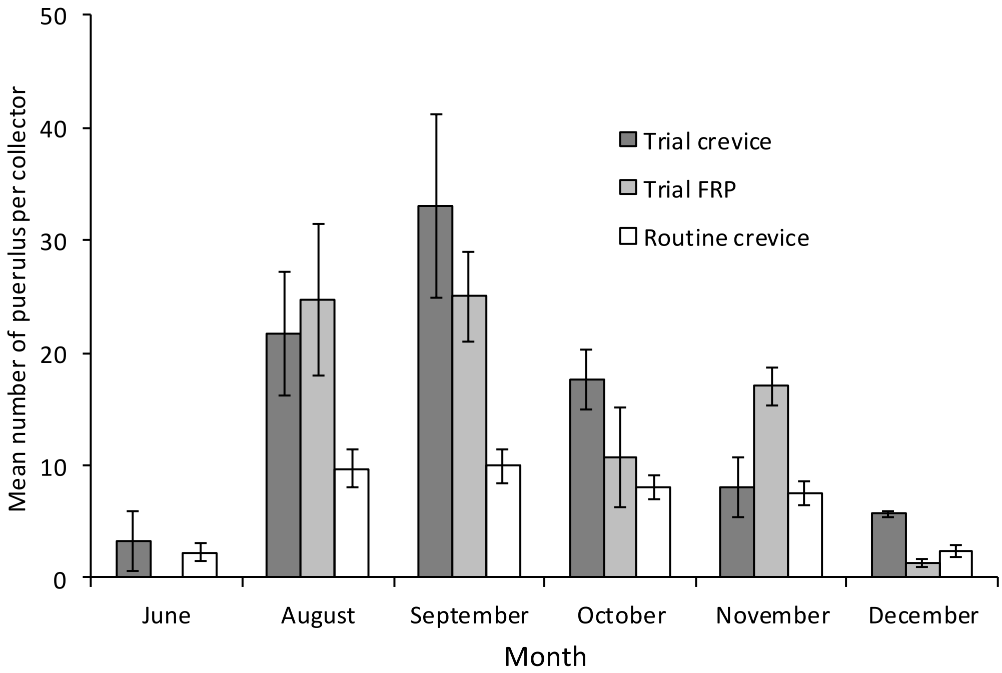

Figure 4: Mean pueruli per collector from the Waubs Bay routine collector site in 2012. The deep water trial collectors feature a stratum housing with a sieve to retain puerulus flushed from the strata during retrieval.

Table 3: P values (t-test) for differences in the number of puerulus collected from June 2012 to December 2012 in trial deep water collectors (featuring a stratum housing with a sieve) and routine collectors (no stratum housing and bagged prior to retrieval). DW and RT refer to deep water trial collectors and routine collectors respectively, and “both” refers to comparisons where both deep water strata are pooled for a comparison. Significant differences in bold type (□□=0.05).

Condition		DW FRP	RT crevice
All months			
	DW crevice	0.72	**0.008**
	DW FRP	-	**0.007**
	DW both	-	**<0.001**
Monthly			
	Jun DW both	-	0.730
	Aug DW both	-	**0.016**
	Sep DW both	-	**0.006**
	Oct DW both	-	0.089
	Nov DW both	-	0.106
	Dec DW both	-	0.371

Settlement rates are higher in the prototype deep water collectors than in the routine inshore puerulus collectors and collection rates are similar between the crevice and FRP strata within the deep water collectors. It is likely that this higher settlement is due to the increased complexity of the habitat offered by the deep water prototype collectors due to the presence of the strata housing and sieve and the reduced entrance area does not appear to limit the ingress of pueruli. Further, given the high settlement rates, it is likely that the sieve is successful in retaining any pueruli that are flushed from the strata during retrieval.

Whilst longer term paired deployments will be necessary to derive a quantitative relationship between the collection rates of the prototype deep water collectors and routine inshore collectors, this comparison indicates that either trial strata used in the deep water collectors will be suitable for monitoring fluctuations in settlement of puerulus in deep water.

7.1.3 Industry workshop

The outcomes from the industry workshop are detailed in Appendix 4. The industry workshop concluded that commercial vessels would be unable to retrieve mooring systems that were larger and heavier than conventional lobster traps. Consequently, a prototype deep water collector was constructed which incorporated the substrate housing into the top of a square steel lobster trap typical of that used in the fishery. In the absence of a heavy mooring, a string configuration each hosting three “pot” collectors was proposed where the interval between collectors was 1.25X the depth to allow each to be landed prior to lifting its neighbour from the seafloor (Fig. 5). This reduced the likelihood that collectors would move across the sea floor under the adverse sea conditions typical of the south and south west coasts of Tasmania by allowing the drag of each trap to contribute to, and benefit from, that of its neighbour.

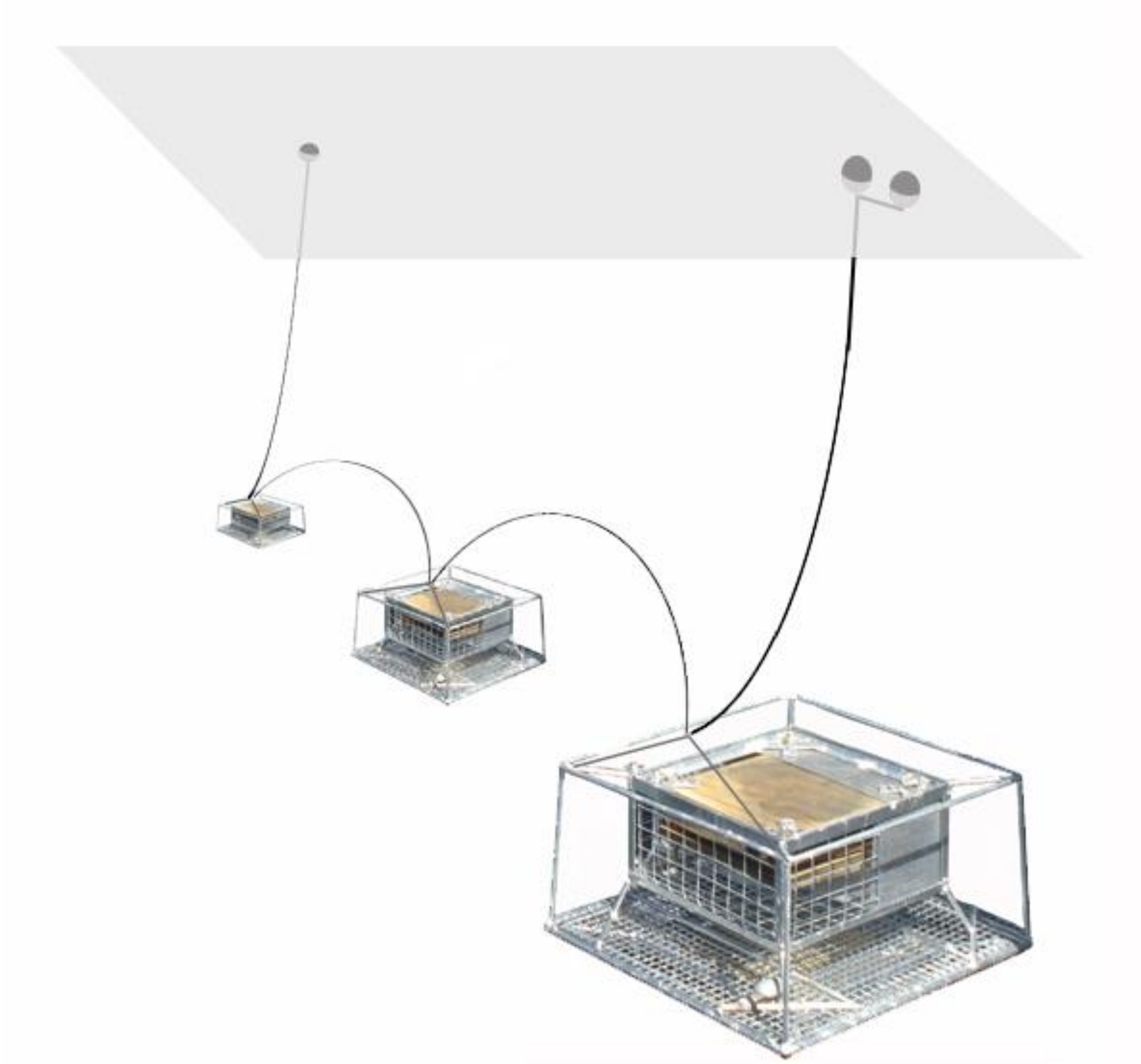

Figure 5: Depiction of the string arrangement of puerulus pot collectors.

7.1.4 Inshore commercial vessel deployment trials

A trial of five successive deployments and retrievals of the prototype “pot” collector into shallow local waters in June 2012 from the deck of a typical commercial lobster vessel demonstrated that this design was within the capacity of the hauling and trap handling gear common in the commercial fleet (Fig. 6). Inspection of the pot collector on the seafloor by diver prior to each retrieval confirmed that the collector consistently landed the right way up (Fig. 7).

Figure 6: Prototype pot collector being retrieved during shallow water trials.

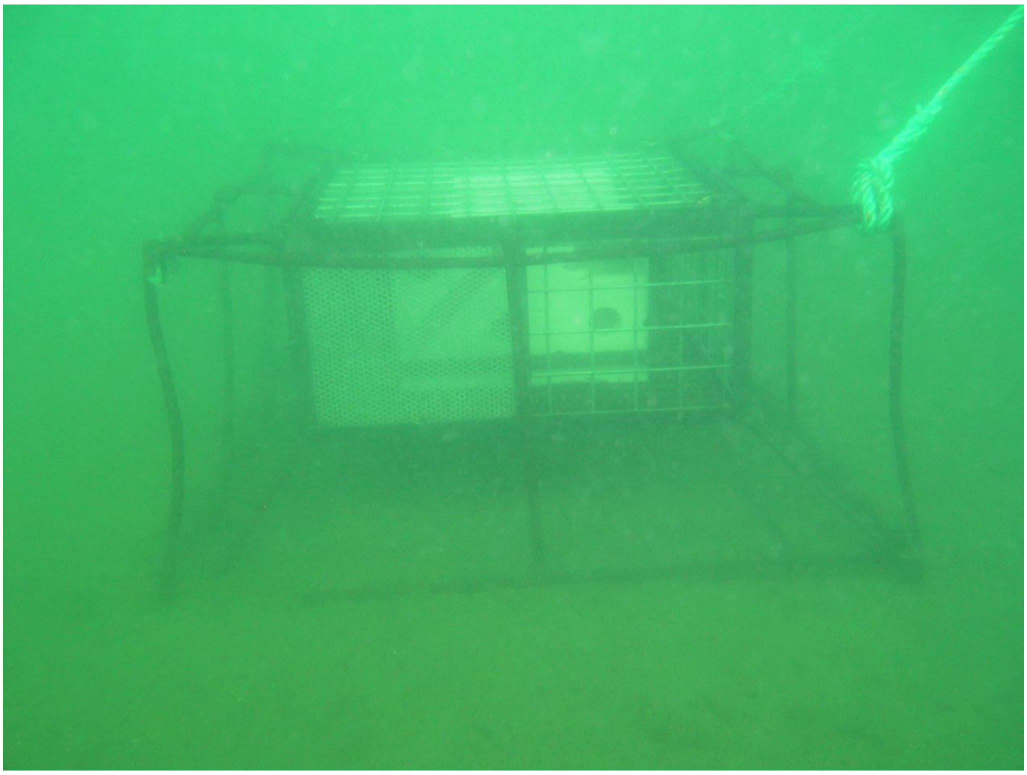

Figure 7: Pot collector oriented correctly on the seafloor during gear trials.

7.1.5 Deployment on the south and south west coasts of Tasmania

The servicing of each string deployed in deep water on the south and southwest coasts of Tasmania was accomplished in around one hour. Feedback from both skipper and crew was positive regarding the ease of servicing due to the design and configuration of the gear and with respect to the capacity of the vessel's hauling gear and the safety of the crew (Fig. 8) (see appendix 6 for industry comments).

Figure 8: Puerulus pot collectors being retrieved and deployed on the south coast of Tasmania.

Similarly, crew have reported that the strata housing design facilitated easy and rapid servicing of the collectors. Other than minor changes to the position of the sieve, suggested by industry, to further increase the likelihood of retention of displaced pueruli, the pot collector design has been enthusiastically supported by industry.

From the servicing of the deep water collectors in December 2012 and January 2013, puerulus have been encountered in collectors at both the south and southwest regions (Table 4). However, no puerulus were caught at the south coast in December 2012. Also, fewer puerulus have been encountered at the deep water sites (Table 4). The collectors yielded a range of other invertebrates and fish (Table 5), and similar assemblages were encountered in in the two regions.

Table 4: Puerulus encountered in the deep water collectors deployed on the south coast (SC) and southwest coast (SW) of Tasmania.

Region	Depth	Date	Number of puerulus
South coast	Shallow	Dec 12	0
	Shallow	Feb13	12
	Deep	Dec12	0
	Deep	Feb13	0
Southwest coast	Shallow	Dec 12	4
	Shallow	Feb13	5
	Deep	Dec 12	0
	Deep	Feb 13	1

Table 5: Taxa encountered in the deep water collectors deployed on the south coast (SC) and southwest coast (SW) of Tasmania in December 2012.

Order / **Family** / **Genus**	**Count by region and depth**			
	South		**Southwest**	
	Shallow	**Deep**	**Shallow**	**Deep**
Isopoda				
Sphaeromatidae				
Cymodoce gaimardii	48	1	7	6
Amphipoda				
Eusuridae	19			
Decapoda				
Alpheidae				
Synalpheus	1			
Palinuridae				
Jasus edwardsii	**12**		**9**	**1**
Diogenidae				
Paguristes	4	60	4	27
Portunidae				
Nectocarcinus tuberculosis	1		1	
Hippolytidae	41	109	154	187
Palaemonidae	99	72	75	134
Majidae	6		1	1
Gastropoda / Opisthobranchia				4
Cephalodpoda				
Octopodidae		1		
Asteroidea				
Asteriidae			1	
Salpida				
Salpidae		4		
Gadiformes				
Moridae				
Psuedophycis	32	6	15	15
Gasterosteiformes				
Syngnathidae				
Hippocampus abdominalis		1	4	

Order / Family / Genus	Count by region and depth: South Shallow	South Deep	Southwest Shallow	Southwest Deep
Scorpaeniformes				
Sebastidae				
Helicolenus percoides	1	4	4	
Perciformes				
Serrandidae				
Caesioperca rasor		1	2	

Low settlement in the routine inshore puerulus collectors is generally experienced in December (mean 2.4 pueruli per collector in December 2012), and settlement is generally low in the first few months of the deployment of newly constructed collector strata as bio-fouling accumulates and "conditions" collectors. Also, the majority of the southwest collectors were assembled incorrectly prior to re-deployment in December and were unlikely to retain as many puerulus flushed from the strata on retrieval in February 2013. These factors may explain the variation in settlement rates encountered in catches of puerulus. However, as the east and west coasts of Tasmania are influenced by separate current systems, the timing of peak puerulus settlement in shallow water east coast collectors may not reflect the timing of settlement in deeper water southern and western sites. The timing and peaks in puerulus settlement are parts of Phase 2 of this project.

Up to 5 individuals from each of the taxa encountered in the collectors has been retained to form a reference collection. This will facilitate on-going monitoring of collector catches to detect seasonal and inter-annual trends in resident animals.

7.2 Development of puerulus monitoring camera system

The prototype remote underwater camera system has been developed using commercially available components and can deliver still images (and engineering data) from multiple cameras once an hour via commercial mobile networks to a CSIRO hosted Sensor Messaging Gateway (SMG) instance. The camera platform is solar powered, energy efficient, remotely reprogrammable, and low-cost. The design utilises common off the shelf hardware components with careful attention to their availability.

7.2.1 Camera system technical description

Hardware components:

- Ledato NanosG20 embedded ARM Linux single board computer (SBC)
- Sierra Wireless Aircard 320u USB 4G modem (GSM/UMTS/WCDMA/LTE)
- Aviosys 9100a 4 channel Ethernet analogue camera server
- Novus RS-485 analogue to digital (ADC) converter
- FTDI based USB to RS-485 converter
- Solid state relays x 2
- 12V / 5V step down DC power supply
- Monocrystaline photovoltaic panel, nominal 12V, 20W maximum power
- 9Ah Sealed Lead Acid (SLA) battery
- Steca Solar Charger

Camera:

- Up to 4 12V analogue PAL cameras
- Two 12V lights powered with camera activation

Communications are provided by the Sierra Wireless Aircard 320u, and this common retail device provides connectivity to all major mobile networks including GSM, WCDMA and LTE. Since the modem is USB based the software can power it off when not in use to reduce power consumption. An Ethernet analogue video capture device is used to provide compatibility with the analogue cameras. The embedded software can use the standard HTTP protocol to retrieve single images. This particular video server, the Aviosys 9100a, was chosen because it was readily available and low-cost. The Novus ADC and the USB RS-485 converter provide an interface for capturing system battery voltage, important for remote health and energy budget monitoring. The power system is nominally 12V and the off the shelf solar regulator provide low battery voltage protection. Figure 9 shows the wiring configuration for these components.

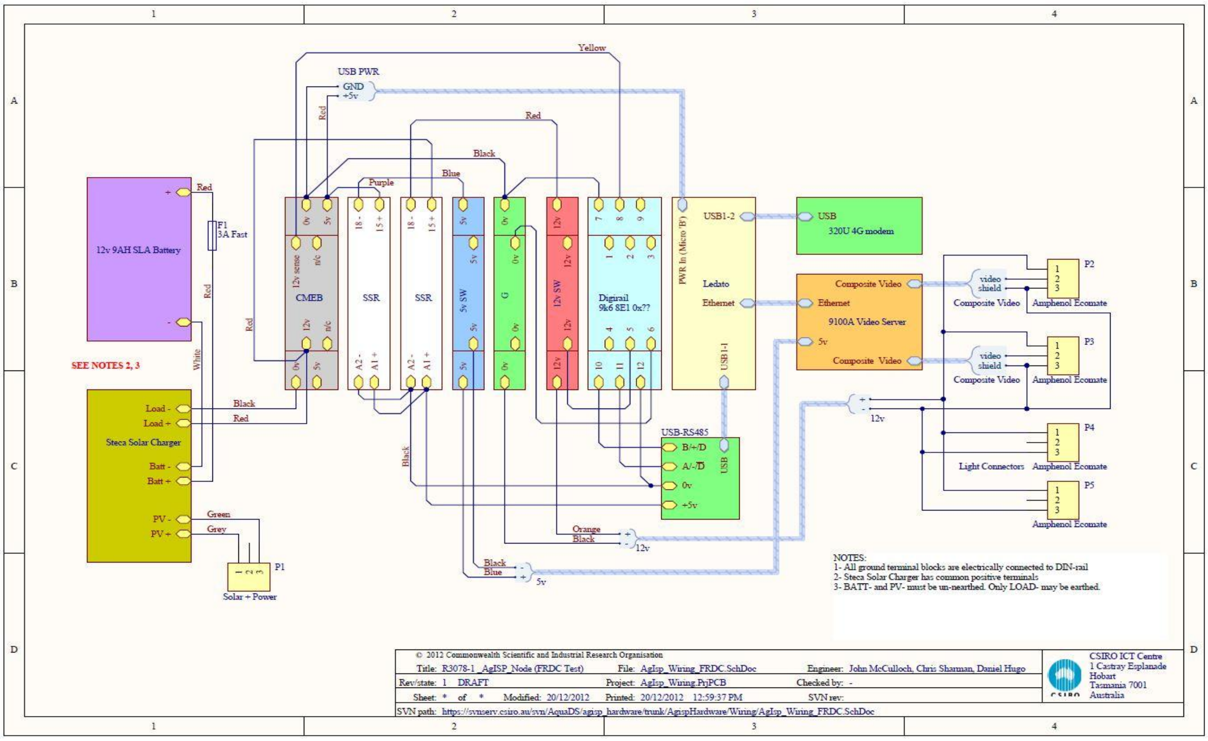

Figure 9: Schematic of puerulus camera system

7.2.2 Computer and Software Architecture

The Ledato SBC forms the heart of the platform, running a standard Debian Linux distribution allowing access to the full open-source community repository of software tools. Importantly the Ledato SBC has a number of power saving features that are not typical in this type of hardware. The first allows a 'suspend to memory' function, supported by the Linux kernel, this allows user to initiate a sleep mode where all peripherals and the CPU core is stopped and only main memory is left running. In this mode the SBC draws approximately 100mW as opposed to 204mW idle after a clean boot. The second major feature is the ability to power down all USB peripherals from software. The USB power control allows the software to easily control power to any attached sensors and modems. The software is written in the Python programming language for ease of management and maintainability.

7.2.3 Power saving strategies

Minimising the power budget for this camera system is critical for it to function remotely and to reduce the cost of components. To this end, the watchdog timer (WDT) hardware based counter, typically provided by SBCs and microcontroller systems, provides a failsafe method of protecting against software failures. This is an important feature for remote systems, especially those reconfigured remotely with limited opportunity for local testing. For the camera platform to meet its energy budget the WDT timer functionality must be interoperable with the suspend-to-memory function discussed above.

The Ledato SBC Linux kernel needed to be altered to use the longest WDT timeout possible (16 seconds) and the boot configuration modified to enable the WDT. In addition the platform has been altered to wake periodically to 'tap' the WDT since the WDT will continue to count even when SBC is suspended to memory. Finally, a time drift problem with the real time clock (RTC) drivers was solved by backporting the latest suspend/resume RTC functions to the Ledato Linux kernel. With these modifications the Ledato board can operate at a low duty cycle in suspended mode whilst also utilising the WDT to recover should any unexpected system errors occur.

7.2.4 Data Transfer Protocols

The software puts the platform to sleep for the configured sampling period, and at the end of this period USB peripherals are enabled. The battery voltage is sampled and stored in a local SQLite3 database. An HTTP connection is established to a CSIRO hosted instance of the Sensor Messaging Gateway (SMG). The SMG software was developed by the CSIRO ISSL specifically for collecting sensor data from a diverse range of sources within one software framework. The sampled data from the SQLite3 database is formatted as JSON and forwarded to the SMG instance. From there the data is merged with streams of sensor data from various sensor networks managed by ISSL. The data is streamed to a JMS publish/subscribe message broker where a second instance of the SMG is configured to subscribe to all data streams and store them in a MongoDB database cluster. The camera image data is not sent via HTTP, but rather via the FTP protocol. The server side end point of the FTP connection is managed by SMG and the data is also forwarded directly to the JMS broker. Another SMG instance is configured to handle image data and saves all images to the web server directory.

7.2.5 Data Delivery

After arriving in the CSIRO hosted infrastructure the sensor time series scalar data is made available via a HTTP RESTful API. The image data is also available via HTTP and a simple web interface is available for browsing images (Fig. 10)

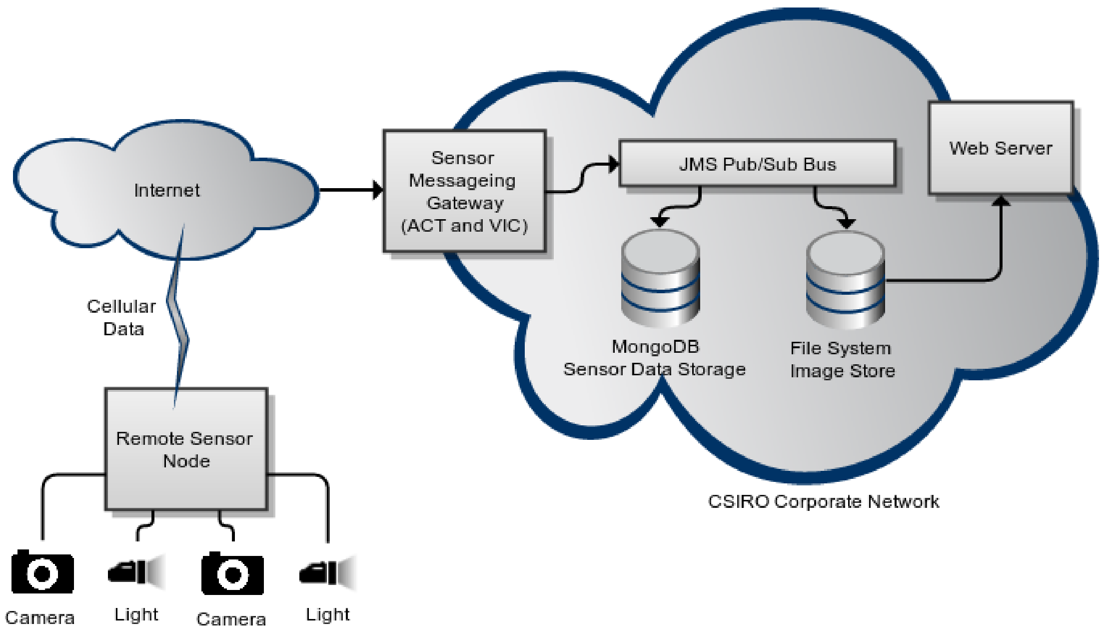

Figure 10: Representation of the captured image data transfer path.

7.2.6 Energy Budget

With two cameras, two lights and electronics the peak power of the camera platform is over 15W. The platform needs to be mounted on a small buoy. When the USB peripherals are powered down and the SBC in suspend mode, the system power drops to around 300mW. With a one hour sample rate the calculated duty cycle is 3.8%, resulting in an estimated average power consumption of 438mW. Using this load value the photovoltaic requirements for southern Tasmania is calculated to be 9W. To allow for some overhead a 20Wp PV panel has been chosen. Sealed lead acid batteries with a capacity of 9AH are common and low-cost; this battery provides 3.6 days of autonomy in inclement weather conditions. These calculations use simple models with a number of assumptions, for this reason large overheads are included. To maximise the life of the SLA battery a maximum depth of discharge (DOD) of 50% has been modelled, also the switching regulator is assumed to have an efficiency of 83% whilst the battery charging efficiency is modelled as 70%.

7.2.7 Buoy and mooring system and camera trials

Following successful desk-top trials at CSIRO the electronic components were installed into a waterproof housing, and this housing and the power supply components (solar, panel, battery and regulator) were installed in a surface buoy (fig. 11). Underwater camera trials have been conducted using habitats seeded with puerulus and examining the relative image quality (and ability to identify puerulus) using a colour camera, and a mono-chrome camera with or without infra-red illumination. These trials demonstrated that the hardware and software systems are fully functional and that puerulus were easily detected in both colour and monochrome images (Fig. 12). However higher resolution images may be required for confident identification of puerulus in the field.

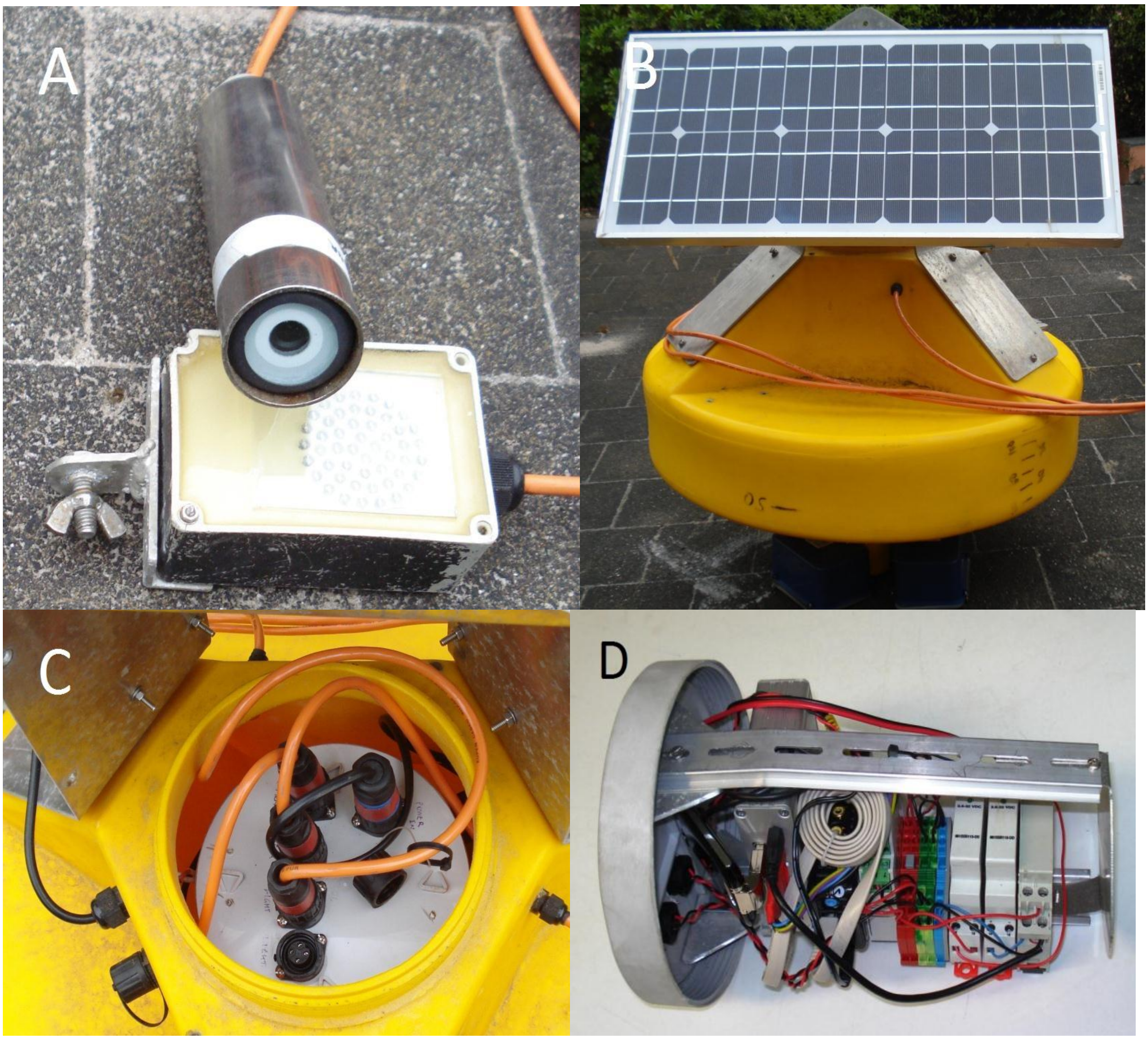

Figure 11: Components of the puerulus monitoring camera system. A: underwater bullet video camera and LED infra-red light array; B: buoy to house electronics and power systems; C: electronics pod mounted in the buoy; D: electronics pod.

7.2.8 Cost

The exact cost of materials is hard to calculate as many on-hand items were utilised. It is estimated electronics hardware cost is below $2500. The telecommunications cost is $10/month which is an entry level mobile data package on commercial 3G/4G networks. The video cameras are around $1200 each, and infra-red lights are around $800 each. These lights and cameras are rated for immersion to around 1500m depth. Allowing around $1000 for a buoy and mooring tackle, the components for a single camera unit would cost around $5500

Figure 11: Underwater images of puerulus and juvenile *J. edwardsii* captured remotely and transmitted to an online server using the 4G network. The larger holes in the strata are 16mm diameter.

8. Benefits and adoption

The prototype deep water collector and remote camera systems developed in this first phase of the project have provided confidence to the fishing industry and government that puerulus monitoring in deeper water in remote and weather impacted regions can be achieved cost-effectively and with industry involvement. This will lead to further investigation into the spatial resolution of settlement and will provide greater certainty for managers and industry regarding the representativeness of the current (shallow) collectors to reflect the entire region.

The camera system offers both the potential to minimise servicing of collectors (both shallow and deep) and also to improve our understanding of the recruitment of puerulus to collectors between servicing and thus improvement in the interpretation of monthly puerulus settlement indices.

The overall project will provide industry and government with an increased ability to forecast recruitment to the fishery, which should improve economic and biological management and planning.

9. Further development

Phase 2 of this project is to deploy the deeper water collectors in each of the key assessment areas over 24 months to determine settlement patterns at depth and to use this data to determine a cost effective sampling regime for longer term monitoring.

A camera system as developed in Phase 1 will be deployed in both shallow and deeper water on collectors to determine the dynamics of recruitment to collectors for improved interpretation of settlement indices. This is likely to be of greater benefit for deeper water collectors when industry sampling may not be achieved at monthly intervals due to weather conditions, seasonal closures or fishing patterns.

10. Planned outcomes

The overall outcome of this project is to design a cost-effective recruitment monitoring program for the Tasmanian rock lobster fishery that covers the key fishing grounds.

Changes in recruitment (settlement) have led to significant changes in resource allocation in lobster fisheries throughout Australia and where quality recruitment indices have been available, adjustments in future catches have provided fishers with a lead in time (several years) to adjust their business decisions to incorporate changes in catch levels. Similarly, managers have been able to make pre-emptive adjustments to catch limits so as to minimise impacts on industry.

The outcome from this project is to place the Tasmanian rock lobster fishery in a position for managers and industry to make decisions as early as possible with respect to change in the resource base. It is also anticipated that outcomes will be adopted broadly across southern rock lobster fisheries and potentially to other lobster fisheries around Australia.

The results of this project have been communicated through distribution of the conclusions of the puerulus collector design workshop to participating Tasmanian rock lobster fishers, state government lobster fishery managers, TSIC, CSIRO and IMAS researchers. Two articles were published in the Tasmanian fishing industry magazine Fishing Today reporting on the methodology and aims (Ewing 2012), and the final outcomes of the collector and camera trials (Ewing 2013). An article reporting the outcomes of the project was also published in the FRDC magazine FISH (Ewing, Frusher *et al.* 2013)

11. Conclusion

Through consultation with industry a deep water collector design has been developed that successfully collects puerulus in both shallow and deep water and that can be successfully deployed, retrieved and serviced by vessels in the commercial lobster fleet.

The collaboration with ISSL and Scielex has been successful in producing a camera system that is capable of capturing images on the seafloor, which can be viewed on any computer with internet access. The low cost and portable nature of this system promote it for purposes such as observing the settlement and behaviour of puerulus on collector monitoring.

Both of these systems offer opportunities for cost-effective monitoring of puerulus, meet the objectives of the first phase of this project.

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13. Appendix 1: Intellectual property

This research is for the public domain. This report and any resulting manuscripts are intended for wide dissemination and promotion. Plans are available for the deep water collector design developed by this project and can be distributed to interested parties. The schematic for the camera system is published within this report.

All data and statistics presented conform to confidentiality arrangements.

14. Appendix 2: Staff

The following table list staff involved in the project:

Name	Organisation	Funding
Ewing, Graeme	IMAS	FRDC and in-kind
Frusher, Stewart	IMAS	FRDC and in-kind
Sharman, Chris	CSIRO	FRDC and in-kind
Treloggen, Rodney	TRLFA	FRDC and in-kind

15. Appendix 3: Letters of support

Kent Way
Clearwater Fisheries
182 Cades Dr.
Kingston, TAS, 7050

Stewart Frusher
Principal Investigator
FRDC project 2011-020

Dear Stewart,

I am writing to provide positive feedback on the development of the prototype deep water puerulus collectors. I feel that my involvement in the workshop for this project and subsequent shallow water trials was productive, my advice was heeded, and that consequently I was able to contribute to producing a good design solution for monitoring puerulus in deep exposed waters.

The pot collector is within the capacity of the hauling gear on my fishing vessel “Chieftain”, and its weight and dimensions are able to be safely handled on deck. The design of the housing (i.e. the strata are suspended under the lid) facilitates easy and quick detection and preservation of puerulus and the gear is sufficiently robust to endure the rigours of work on deck at sea.

I envisage that these collectors will be able to be deployed in a variety of locations where traditional approaches to puerulus monitoring are not possible due to depth, and/or exposure.

These collectors should provide a cost-effective means of expanding the puerulus monitoring program in Tasmania.

Regards
Kent Way
23/1/2013

Tasmanian Rock Lobster Fisherman's Association.

John Sansom
President
Tasmanian Rock Lobster
Fishermen's Association
PO Box 195
St Helens Tas 7216

Stewart Frusher
Principal Investigator
FRDC project 2011-020

Dear Stewart,

I am writing to provide positive feedback on the progress achieved so far on the FRDC project *Developing cost-effective industry based techniques for monitoring puerulus settlement in all conditions: trials in southern and western Tasmania*. I feel that the successful consultation between project staff and lobster fishers has ensured that the subsequent collector design can be deployed, retrieved and serviced safely onboard commercial vessels. I also believe that this consultation has successfully engendered interest, and a desire for involvement with this project, within industry.

The collector design looks to be sufficiently robust to withstand the rigours of the adverse sea conditions regularly experienced in southern Tasmania. I was pleased to hear that the collector has successfully retained puerulus settlers to the surface on the southwest coast.

I feel that this design of collector can provide a cost-effective means of expanding the range over which puerulus are monitored in Tasmania, improving management, and benefiting fishers.

Regards
John Sansom
23/1/2013

16. Appendix 3: Review of puerulus settlement

Jasus edwardsii are present in significant densities in deeper waters as demonstrated by around 30% of landings in the fishery on the Tasmanian west and southwest coasts taken in waters deeper than 60m (Hartman, Gardner *et al.* 2012). Settlement of *J. edwardsii* pueruli in shallow inshore waters (<10m) is well documented with long-term research programs monitoring settlers in southern Australian and New Zealand. The settlement of *J. edwardsii* pueruli in shallow inshore waters in Tasmanian has been monitored for over two decades and has revealed considerable spatial and temporal variation in settlement (Cohen and Gardner 2007; Gardner, Frusher *et al.* 2001). Given significant densities of *J. edwardsii* in deeper water, and clear evidence of settlement in shallow water, lobsters must settle inshore and then move to deeper water, settle directly into deeper water, or both.

Settlement of puerulus inshore on specific shallow water habitats, with subsequent migration offshore and/or upstream to adult habitats, is a life-cycle common in palinurid lobsters (Booth 1997; George 2005; Phillips 1983; Phillips, Melville-Smith *et al.* 2007). However, puerulus from some palinurid species are known to settle directly into deep water adult habitats (Polovina, Haight *et al.* 1995). Puerulus of *Jasus spp.* swim strongly from offshore and shelf slope habitats, actively seeking settlement habitats (George 2005).

If movement after settlement from shallow inshore sites is responsible for the populations of larger lobsters on deeper water sites, this movement could be either migratory (directed and temporally discreet), or nomadic (wandering lacking directedness and temporal confinement). Research using acoustic telemetry to measure medium-scale movement of *J. edwardsii* on inshore reefs in New Zealand reported that, although exhibiting home-ranging movements associated with moulting, reproductive and feeding cycles, *J. edwardsii* display high site fidelity with a maximum recorded range of 3.1km (Kelly 2001; Kelly and MacDiarmid 2003; MacDiarmid, Hickey *et al.* 1991). Whilst trap-based tag and recapture methods of detecting movement are insensitive to small scale movements (Booth 1997), such studies can be used to detect large scale migratory or nomadic movements (Gardner, Frusher *et al.* 2003). Trap-based mark and recapture studies of *J. edwardsii* in New Zealand waters have shown clear evidence of alongshore, contranatant movement and this movement is mostly in juvenile females approaching maturity and similarly sized males (Booth 1997).

Analysis of tag recapture data of *J. edwardsii* in Tasmanian waters (~40,000 recaptures) shows little evidence of large-scale unidirectional or nomadic movement, but some evidence of seasonal movements associated with moulting of males and larval release by females (Barrett, Buxton *et al.* 2009; Gardner, Frusher *et al.* 2003). For example, on the south west coast of Tasmania tag recapture data indicates a 10% movement from shallow to deep water, and a 39% movement from deep to shallow (Green, Gardner *et al.* In prep). Whilst the size selectivity of the traps used for this research has been shown to vary with sex and season (Ziegler, Johnson *et al.* 2002), the trap selectivity of lobsters >80mm carapace length (CL) is considered sufficient to conclude that if offshore movement is responsible for the density of *J. edwardsii* in deeper sites, it must be due to movement of small post settlers (< 80mm CL).

Early juvenile palinurid lobsters are very vulnerable to predation, which they counter with cryptic behaviour and by sheltering in complex micro-habitat (Groeneveld, Greengrass *et al.* 2010). Nomadic short-distance movements to find increasingly larger close-fitting holes and food-items are necessary for fast growing small juvenile lobsters (Booth 2001), but are unlikely to involve movement over larger distances due to a high risk of predation. This is particularly the case in Tasmania as movement into deeper waters generally entails movement to habitats of lower productivity than those inshore (Gardner, Frusher *et al.* 2006), and in some locations entails migration across extensive areas of soft sediment. Further, of the palinurids that do migrate offshore from settler habitats, this movement occurs at, or just prior to, maturity (Kanciruk 1980), rather than in early juvenile post-settlement phases.

Extensive Tasmanian tagging studies provide no evidence for a systematic offshore migration in adult or near mature *J. edwardsii*, and a systematic migration of young juveniles is inconsistent with observed behaviours and would carry a very high risk of predation. Consequently, it is likely that populations of adult *J. edwardsii* encountered on deeper reefs have originated largely from puerulus settling directly in deeper waters.

Cues to metamorphosis from phyllosoma to puerulus are thought to involve threshold energy states sufficient to allow a non-feeding puerulus to swim ashore (Phillips and McWilliam 1986) and possible environmental triggers for *J. edwardsii* (Jeffs, Chiswell et al. 2001). Studies of the lipid reserves in *J. edwardsii* pueruli on the outer shelf in New Zealand found that over 15% had insufficient energy reserves to reach inshore settlement sites (Jeffs, Chiswell *et al.* 2001). The inshore migration of *J. edwardsii* pueruli across the shelf, also involves a diurnal vertical migration with daytime spent on the seafloor and night-time spent at the surface (Booth and Phillips 1994; Jeffs, Chiswell *et al.* 2001). Puerulus are known to utilise surface onshore currents to assist their migration to inshore waters (Groeneveld, Greengrass *et al.* 2010), with pulses in inshore settlement corresponding with down-welling events.

Consequently, it is likely that *J. edwardsii* pueruli encounter the sea floor at various points on the shelf due to diurnal vertical migration and/or insufficient energy reserves to reach inshore waters. Further, unfavourable surface currents would be likely to increase the number of encounters with the seafloor due to slower progress across the shelf and an increased likelihood that energy reserves would be depleted prior to reaching inshore waters. Habitat selection of invertebrates has been shown to be driven by factors such as the presence of conspecific adults, other new recruits, other taxa (such as prey species) and the type and texture of substrates. Booth (2001) reported that *J. edwardsii* chose suitable shelter above these other factors.

In research on the East coast of New Zealand, Booth *et al* (1991) established that *J. edwardsii* pueruli settled to depths of at least 50m, that settlement increased with depth to around 10 to 12m, after which it decreased with increasing depth and distance from shore. Given the lack of evidence for post-settlement migration in Tasmanian waters, the likelihood that puerulus encounter structured habitats suitable for settlement in deeper water whilst migrating inshore, and the primary importance of shelter quality in selection of settlement habitats; it is likely that *J. edwardsii* settle directly onto deep water reefs. Further, settlement rates in deep water may vary relative to shallow settlement rates on the basis of factors which influence the likelihood of pueruli having sufficient energy to migrate to inshore waters for settlement. These factors may include the distance from the shore at which metamorphosis from phyllosomata occurs, the lipid content of puerulus, the surface current conditions in shelf waters, and the occurrence of suitable settlement strata in shelf waters.

17. Appendix 4: Review of puerulus collectors

Numerous materials have been utilised to simulate desirable habitat for puerulus settlement for the purposes of monitoring recruitment variability and for commercial harvest for mariculture. A selection of collector designs that have yielded high rates of puerulus settlement in the coastal waters of countries including Australia, New Zealand, United States, Mexico, Japan, India and Cuba, are summarised below.

i. **Plate crevice collectors** are constructed with 16 squares of plywood, held in a galvanised steel frame with bolts in the corners and PVC conduit spacers producing 15 wedge-shaped crevices suitable. Plate crevice collectors fixed rigidly to the seafloor on moorings have successfully collected puerulus for inshore puerulus settlement monitoring programs in southern Australia and New Zealand (Booth and Tarring 1986; Gardner, Frusher et al. 2001) (Fig. 1a). Floating tethered crevice collectors were also successful in collecting puerulus in commercial harvest trials (Mills and Crear 2004) (Fig. 1b).

ii. **Mesh collectors** are comprised of mesh enclosures containing natural or artificial strata that provides complex convoluted habitat suitable for puerulus settlement. Mesh cylinders or bags of plastic oyster mesh filled with heavy trawl mesh or Black wind-break mesh were successful in collecting pueruli in research into commercial harvest of puerulus (Mills and Crear 2004) (Fig. 1c). Nylon bags containing surf-grass and red algae were also successful in collecting pueruli in California (Serfling 1975).

iii. **Witham-style collectors** are constructed of leaves of fibrous material folded over horizontal rails and buoyed at the surface. Each leaf supports a matrix of filaments composed of nylon, vinyl (Witham, Ingle et al. 1968) (Fig. 1d), or hogs hair (Miller and Goodwin 1989) and pueruli settle in the gaps between the leaves. Witham collectors have successfully collected puerulus in Florida, Hawaii, and the Caribbean (Phillips and Booth 1994).

iv. **Phillips collectors** consist of three vertically mounted rectangular plates arranged in a vertical prism and buoyed to just reach the sea surface. Each plate has 25 polypropylene tassels simulating seagrass or kelp and providing structured habitat for settlement (Phillips 1972) (Fig. 1e). Phillips collectors have been used in Western Australia (Phillips and Booth 1994) and Cuba (Cruz, Diaz *et al.* 2001) to collect puerulus.

v. **Sandwich collectors**, a modified version of the Phillips collector, consisting of 2 sheets of grey industrial PVC with bales of tassels attached to the outside of the sheets (Fig. 1f). Sandwich collectors have been shown to be highly effective in collecting puerulus (Phillips, Cheng *et al.* 2005; Phillips, Melville-Smith *et al.* 2001).

vi. **GuSi collectors** are an inexpensive puerulus collector constructed of bands of synthetic strapping, frayed to form tassels, and wound around a 19L plastic bucket (Fig. 1g). This collector has been used to study puerulus settlement in Mexico (Guzman-del Proo, Carrillo-Laguna *et al.* 1996).

vii. **Bottlebrush collectors** are comprised of stacked rosettes of black wind-break mesh on a central shaft. These collectors are inexpensive and successfully collected pueruli in commercial collection trials (Mills and Crear 2004) (Fig. 1h).

viii. **Aerated concrete blocks** (Hebel□□□ with an array of drilled holes, have been shown to provide refugia for pueruli (Dennis, Ye *et al.* 2004; Edmunds 1995) (Fig. 1i).

Designs that successfully collect puerulus include complex habitat in either rigid material (crevice, sandwich and block collectors) or convoluted flexible material (mesh, Witham, GuSi, and bottlebrush collectors). Consequently, the primary function of the collector seems to be to provide shelter. Weed or weed-like material correlates with higher rates of settlement (Ibbott and Gardner 2002), and a number of collector designs incorporate this feature (mesh, Witham, Phillips, GuSi, and bottlebrush collectors). This suggests that pueruli may be seduced from the water column by suspended weed due to the likelihood that weed is anchored to hard substrate that may provide shelter. This explanation is supported by higher densities of pueruli in holes adjacent to stems and holdfasts of algae (Norman and Morikawa 1996).

Successful collector designs will first encourage settlement and subsequently retain settled pueruli. The desirability of a collector design appears to vary among species, with *Panulirus* spp. preferring weed-type shelter and *Jasus* spp. preferring crevice-type shelter (Phillips and Booth 1994), although this trend is not unequivocal (Mills and Crear 2004). Further, the most appropriate collector is also likely to depend on other factors such as the coastal features where the collectors are deployed (Phillips and Booth 1994). Booth (2001) conducted laboratory tank experiments on the habitat preferences of *J. edwardsii* pueruli and concluded that they prefer refuges with firm surfaces over soft, conditioned over unconditioned, horizontal openings over vertical, and rough surfaces over smooth.

Comparisons in New Zealand, South Australian and Tasmanian waters yielded equal or higher numbers of *J. edwardsii* settlers in crevice collector (rigid horizontal refuge), than in Phillips simulated seaweed collectors (soft flexible refuge) (Kennedy 1991; Phillips and Booth 1994). However, Mills and Crear (2004) found that *J. edwardsii* settled on a variety of materials, including flexible strata, some bearing little resemblance to features in their natural habitat. Palinurid lobster rearing trials conducted at the IMAS laboratories have found that puerulus and early juveniles also utilise FRP grid mesh for shelter (Fig. j).

The crevice puerulus collectors used in shallow inshore Tasmanian waters are manually "bagged" in fine mesh sacks by divers prior to being hauled to the surface to eliminate losses of puerulus in the water column. Research in shallow inshore Tasmanian waters has shown that losses of puerulus from un-bagged collectors are minimal (Mills and Crear 2004). However, retrieval of collectors from deep water, and particularly the potential for flushing at the surface under adverse sea conditions, may lead to significant losses of puerulus. Consequently, minimising the loss of puerulus during retrieval must also been considered in the assessment of potential collector systems for deep water.

Figure 1: Collector materials and designs known to successfully collect puerulus (a - crevice; b – floating crevice; c – mesh bag; d – Witham; e – Phillips; f – sandwich ; g – GuSi; h – bottlebrush; i - Hebel□□□j – FRP gridmesh).

18. Appendix 5: Industry workshop

Outcomes from deep-water puerulus project workshop – 28/2/2012

Attendees
Brendan Taylor – Fisher
Kent Way – Fisher
Neil Stump – TSIC
Chris Sharman – CSIRO
Stewart Frusher – IMAS
David Faloon – IMAS
Graeme Ewing - IMAS

Project background and need

In Australia, lobster larval (puerulus) collectors have been deployed to observe larval settlement and to improve our understanding of the relationship between recruitment, future catches and short and long term recruitment trends. Puerulus collectors are serviced by divers (SA, Tas & Vic) and from dinghies (WA) and consequently, collector sites have been limited to shallow inshore waters, and to a small number of locations. Given that the majority of the catch in the Tasmanian southern rock lobster fishery (*Jasus edwardsii*) is taken from deeper waters and from the southern and western regions, where no collectors have been successfully deployed, there is a need to develop a cost-effective method of deploying and servicing collectors in deeper water to improve spatial (region and depth) coverage. This need was recognised in a review of the puerulus program undertaken in 2008 that involved government and industry and identified the priority to investigate options for puerulus collection on the west coast using the commercial fleet to reduce costs.
This is phase 1, of a 3 phase project with the ultimate aim to develop cost-effective collectors that can be used to provide an early warning of changes in puerulus settlement that can be used to improve management of the fishery. Such collectors will need to withstand all weather conditions, be serviced in deeper water and be serviced by the fishing industry throughout southern Australia.
The project will also investigate the potential of an underwater camera system to monitor settlement. An underwater camera and transmission system, being developed for other applications by CSIRO ICT Centre, will relay pictures to the IMAS laboratory and will be evaluated for reducing puerulus monitoring costs and for improving our knowledge of puerulus settlement and thus recruitment to the fishery. As photos will be taken over 24 hours each day, we will also be able to investigate puerulus settlement behaviour, such as whether puerulus arrive in groups or individually, their retention time on collectors, and the reliability of monthly puerulus counts as a measure of settlement activity. This information is expected to aid in refining the relationship between observed puerulus settlement and future predicted catches for the fishery.

Collector design for deep water collection of *J. edwardsii* puerulus in Tasmanian waters

This study aims to develop and trial designs of collectors for monitoring puerulus settlement in deep water on the coast of Tasmania that are suitable for deployment, retrieval and servicing by vessels from the commercial lobster fleet. Each puerulus collector design will incorporate settlement strata (which provides a desirable habitat), a collector base on which to mount settlement strata on the seafloor, a means of retrieval such as buoy-line and surface buoy, and possibly, additional mooring material to ensure that the collectors remain stationary on the seafloor.
The crevice puerulus collectors used in shallow inshore Tasmanian waters are manually “bagged” in fine mesh sacks by divers prior to being hauled to the surface to eliminate losses of puerulus in the water column. Research in shallow inshore Tasmanian waters has shown that losses of puerulus from un-bagged collectors are minimal (Mills and Crear 2004). However, retrieval of collectors from deep

water, and particularly the potential for flushing at the surface under adverse sea conditions, may lead to significant losses of puerulus. Consequently, minimising the loss of puerulus during retrieval has also been considered in the assessment of potential collector systems.

Settlement substrata

Considerations for the selection of settlement strata for monitoring settlement of puerulus in deep water include maximising settlement rates and precision, minimising loss of settled pueruli due to flushing on retrieval, ease and safety of servicing on deck, minimising the volume and weight of materials required for servicing, and minimising cost. Table 1 summarises the relative advantages and disadvantages of various settlement strata.

Table 1: The relative merits of different collector types for use in collection of puerulus from deep water.

Collector type	*Advantages*	*Disadvantages*
Crevice	Hard, rough surface Horizontal openings High settlement	Time-consuming to service Heavy Pueruli likely to be flushed out High volume of material onboard
Mesh	Cheap Easy and quick to service Pueruli unlikely to be flushed out Low volume of material onboard	Lower settlement
Witham	Cheap Easy and quick to service	Pueruli likely to be flushed out
Bottlebrush	Cheap Easy and quick to service	Pueruli likely to be flushed out
Filament	Cheap Easy and quick to service High settlement	Pueruli likely to be flushed out
Hebel	Cheap Hard, rough surface Pueruli unlikely to be flushed out Horizontal openings High settlement	Heavy and brittle High volume of material onboard
FRP mesh	Cheap Easy and quick to service Likely high settlement Pueruli unlikely to be flushed out	Heavy

Collector base, buoys, lines and moorings

As the purpose of this project is to measure puerulus settlement at depth, collectors need to be positioned near the sea floor. Research has shown that puerulus settlement is higher just above the sea floor (Norman and Morikawa 1996) and that *J. edwardsii* pueruli prefer rigid strata in preference to floating. Consequently, the supporting structure for deep water collection will firmly position the settlement strata just above the seafloor, and provide a means of retrieval suitable for use by vessels in the Tasmanian commercial lobster fleet. The components of such a system are:

- a strata housing to protect the strata (and pueruli) from damage through impact and to reduce loss of puerulus through flushing;
- A collector base on which to attach the strata housing and that will ensure that its position is upright and stable.
- A buoy and line system - to allow routine retrieval of the collector for removal of pueruli and servicing of its components. Acoustic release buoy systems are available which eliminate the necessity for a surface buoy.

And possibly,

- A mooring – a heavy mooring separate from the collector base, and sufficiently massive to ensure that collectors do not move across the seafloor.

The requirements for the ground tackle, lines and buoys for this project include:

- Collectors to be safely retrieved and serviced by vessels from the lobster fleet, even under adverse sea conditions
- The gear to be lifted to service a collector is within the lift capacity of the haulers in the lobster fleet
- The buoy line gauge is within the usable range of the haulers in the lobster fleet
- The buoy line gauge, ground tackle, and buoy sizes are balanced to allow retrieval in adverse tidal streams
- The gear is assembled such that chafe and fouling will not preclude retrieval or cause failure
- Maximising the likelihood that collectors will remain stationary on the seafloor

Possible gear configurations that fulfil these requirements include:

- A single pot-like base with collector attached with a surface buoy
- A string of pot-like bases buoyed at either end
- A string of pot-like bases with the last pot tethered to a larger mooring which is not lifted from the seafloor during routine servicing
- A buoy line with chain or billet weights (within the lift capacity of the fleet) to minimise movement and a string of smaller bases
- Any of these ground gear configurations can be fitted with an acoustic buoy release system which eliminates the necessity for a surface buoy.

Table 2 summarises the relative advantages and disadvantages of these ground gear configurations for positioning the settlement strata firmly near the seafloor, and for retrieval, servicing and re-deployment by lobster fishing vessels.

Table 2: The relative merits of these gear configurations are listed below.

Collector type	Advantages	Disadvantages
Single pot	Safe and easy to retrieve and deploy due to familiarity Within the lift capacity of haulers Inexpensive	More surface buoys required for replication Possible movement in heavy conditions
String of pots	Replication with fewer surface buoys Inexpensive Less likely to move than single collector systems	Possibly beyond vessel lift capacity More difficult than single pot systems to service
String of pots with mooring	Replication with fewer surface buoys Unlikely to move under any conditions	Additional cost of mooring and deployment Quite difficult to service Possibly beyond vessel lift capacity
Acoustic line release	No exposure to theft, vandalism or accidental entanglement No fouling are drag issues	Expensive High failure rate Can't be reloaded by lobster vessels

Discussions at the workshop concluded that a system of 3 to 4 collectors, of around 40kg (in air) each, "daisy chained" on the sea-floor, with linking lines of around 1.25 times the depth, would be unlikely to move under adverse sea conditions, and could be safely serviced by most vessels in the lobster fleet. The housing for the settlement strata is a steel framed box with mesh panels (Fig. 2). This frame will provide adequate protection for strata and the use of 3mm perforated steel mesh for the components of the housing that are downstream during hauling will increase the likelihood of retaining pueruli flushed from the strata during retrieval. Settlement strata will be attached to the underside of the lid of the housing to facilitate removal of puerulus on deck (Fig. 2).
Strata housings will be mounted on traditional steel lobster pots, as commonly used in the fishery. These pots will not be meshed, and will have additional steel bars incorporated in the base to improve stability and achieve the target weight of 40kg.

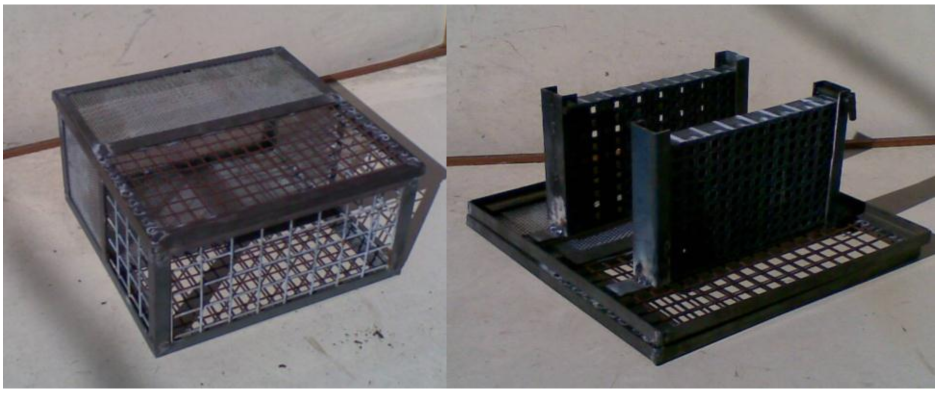

Figure 2: Housing for settlement strata (left) to be mounted on the collector base and a housing lid showing FRP grid mesh settlement strata mounting (right). The mesh sieve to retain puerulus flushed out of the strata during retrieval is at the back and left of these images.

Buoy lines to be used are 12mm polyethylene, surface buoys will be "current" buoys to maximise the likelihood that the buoys would stay on the surface during tidal flows, and will also include a Dan buoy with a radar reflector. The linking line on the seafloor between collectors will be 14mm candyline, and an additional 10mm safety buoy-line will be attached to the last collector. To further minimise the likelihood of movement in adverse sea conditions the first collector in the chain will be carry additional weight (to a total weight of 50kg in air) (Fig. 3).

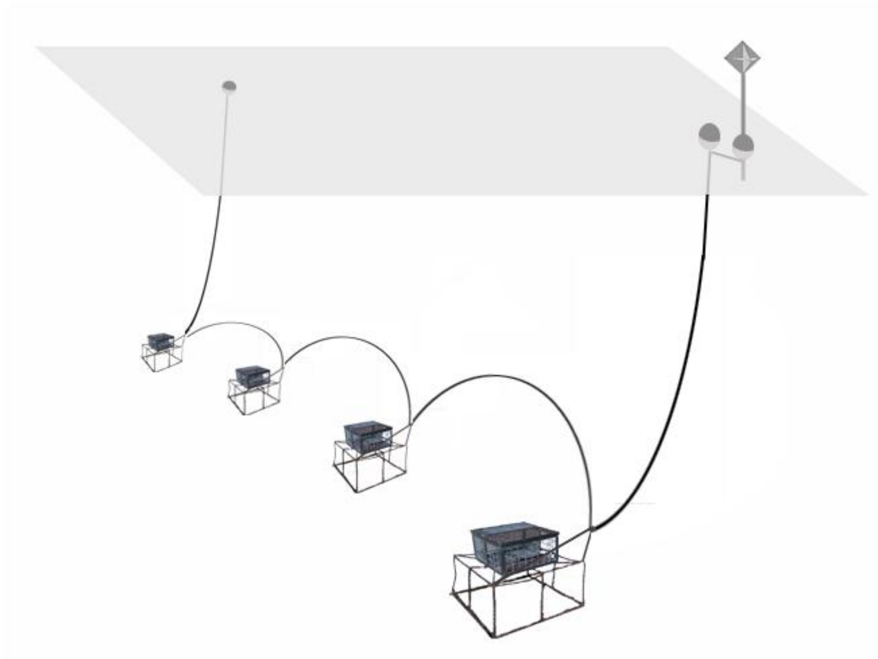

Figure 3: A representation of the gear configuration that will be used for positioning puerulus collectors on the seafloor in deep water.

A prototype of this pot collector design has been deployed from the deck of the *Chieftain* and, with the exception of some minor changes, has proved safe to deploy and retrieve (Fig. 4). A prototype string of pot collectors will be deployed and retrieved from a commercial lobster vessel in local waters in mid-April to further test this collector system. Divers will inspect the string prior to retrieval to ensure that collectors are sufficiently self-righting.

Following any further modifications identified in local trials, collectors will be deployed on soft sediment on the south and south west coasts of Tasmania in depths from 50 to 150m from around July 2012. Sites have been chosen on the bases of; providing soft sediment in target depths; minimising the likelihood of accidental fouling of buoy lines by other vessels by positioning collectors away from popular routes; and minimising the inconvenience to servicing vessels from the commercial fleet.

Servicing collectors will be conducted approximately monthly and will entail retrieval (Fig. 4), removal of the strata housing lid (with strata attached), retention of any puerulus settlers in the strata or sieved in the housing, removal of fouling and redeployment to the seafloor.

The sites chosen in the workshop for initial deep water trials on the Tasmanian south west coast are: south east of the Pyramids (depth ~60m); and south west of the Pyramids (~150m) (Fig. 5). The sites chosen for deep water trials on the south coast are south of Cox Bight (~60m) and between Maatsuyker Island and South West Cape (~110m) (Fig. 5). Strings of four collectors each will be deployed at each site. Each string will include one of each of the settlement strata chosen for sea trials (crevice, mesh, Hebel and FRP grid). This will allow the relative performance of each settlement strata to be assessed, at each site.

Figure 4: Prototype collector on tipper used for retrieval.

Twelve settlement strata housings, three of each settlement strata, will also be deployed at an existing shallow water crevice collector array at Bicheno around May 2012. This will allow comparison of settlement rates between crevice collectors with and without a meshed housing, and will provide further comparisons between strata designs. These collectors (and housings) will be mounted directly on concrete and steel collector bases (Fig. 1a) (rather than pot collector bases). Collectors will be randomly allocated to bases each time they are serviced to avoid confounding due to collector interactions.

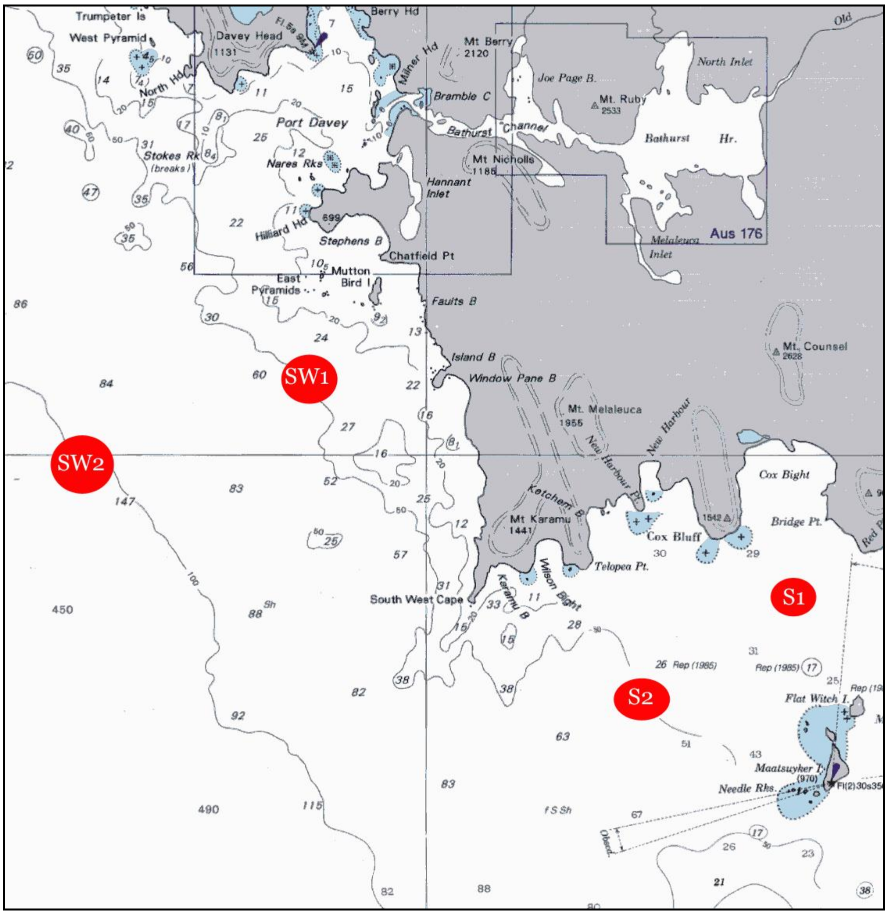

Figure 5: Map showing potential sites for deep water puerulus collector deployments on the southern and south western Tasmanian coasts.

19. Appendix 6: Deep water collector log sheets

Deep water puerulus collector servicing instructions

Haul details
Record the Date and time, and the position of the double buoyed end.

Minimise loss of pueruli
Haul the collectors (where possible from the double buoyed end). Where possible, haul slowly to minimise the loss of puerulus through turbulence, and try to minimise flushing at the surface.

While handling the collector, if possible, keep the sieve side of the pot lower than the open mesh side to minimise loss of puerulus. If possible, stand collectors on their side on deck to keep the sieve lowest.

Service the collector
Remove the lid of the collector, with the substrate attached, and place in a sieved bin.

Check the sieve of the collector for puerulus and other animals:

- Record the number of puerulus in the sieve of the collector and place in the correct jar with preservative (see below for Jar codes).
- Put aside other animals in the sieve. These will be preserved if there is room in the jar.

Check the collector substrate for puerulus and other animals:

- Record the number of puerulus in the substrate and place in the correct jar with preservative (see below for Jar codes).
- Put aside other animals in the substrate. These will be preserved if there is room in the jar.
- Check the sieved bin for missed pueruli.

Clear off excessive fouling and reassemble.

Re-Deploy the collector string
Record the position of the both the single mooring and the double mooring ends of the collector string, and the date and time deployed.

Jar coding
The first 2 letters of the Jar code denote region (SC = South Coast, SW = South west); the 3rd letter denotes depth (S = Shallow, D = Deep), the 1st number denotes the string of pots (2 strings per site); and the last letter denotes the position of the collector on the string (*a* at the double buoy end)

Deep Water Puerulus service log

Site	Date	Time	Lat/Long Haul	ply	grid	Jar Num	Puerulus in sieve	Puerulus in substrate	Lat/Long deploy Single buoy	Lat/Long deploy Double buoy	Comments
Pyramids Shallow 1a						**SWS1a**					
Pyramids Shallow 1b						**SWS1b**					
Pyramids Shallow 1c						**SWS1c**					
Pyramids Shallow 2a						**SWS2a**					
Pyramids Shallow 2b						**SWS2b**					
Pyramids Shallow 2c						**SWS2c**					
Pyramids Deep 1a						**SWD1a**					
Pyramids Deep 1b						**SWD1b**					
Pyramids Deep 1c						**SWD1c**					
Pyramids Deep 2a						**SWD2a**					
Pyramids Deep 2b						**SWD2b**					
Pyramids Deep 2c						**SWD2c**					