PROCEEDINGS OF THE 2018 CENTROSTEPHANUS FORUM

Blundstone Arena, Bellerive, Tasmania
14 December 2018

Wild Fisheries Management Branch
Department of Primary Industries, Parks, Water and Environment

Tasmanian Government

Contents

This document was prepared by Ian Cartwright, Kelsey Richardson with input from Ian Dutton, Vicki Waters and staff of the Wild Fisheries Management Branch at DPIPWE and at the Institute for Marine and Antarctic Studies (IMAS) at the University of Tasmania.

1. Introduction

1.1 Background of Centrostephanus in Tasmania

The longspined sea urchin, *Centrostephanus rodgersii*[1], is native to New South Wales (NSW) on mainland Australia, where Centro 'urchin barrens' habitat constitute approximately 50% of all near-shore rocky reef. Centro was first recorded in far northeastern Tasmanian state waters in the 1970s, and continued its range extension southeast along the state with early reports of Centro on mainland Tasmania in 1978, documented cases of Centro in southeastern Tasmania by the 1990s, and recent recordings of Centro in southwestern Tasmania. This range extension is consistent with a strengthening of the East Australian Current, which transports long-lived planktotrophic urchin larvae to the east coast of Tasmania, combined with warming winter ocean temperatures that have surpassed the12 degree threshold required to support urchin larvae development.

Without adequate levels of natural biological controls to temper the spread of these invasive urchins, the introduction of Centro to Tasmania is resulting in the overgrazing of native kelp forests. Centro recruitment increases as kelp is grazed and removed, transitioning once healthy kelp beds to incipient, patchy barrens and, with time, to more extensive barrens that are completely denuded and devoid of marine life. Once barrens have formed, recovery back to their previous kelp bed ecosystems is a significant challenge. Observations show kelp cover collapses at densities of $\geq$2.2 urchins m^{-2} (550 g m^{-2}). Kelp bed recovery has been observed to occur with densities $\leq$0.4 urchins m^{-2} (70 g m^{-2}). These barrens have serious impacts on the surrounding marine environment and wild fisheries on the east coast of Tasmania as native ecosystems are compromised and fisheries stocks are depleted. Several hundred kilometers of Tasmanian coastline have already been affected by Centro overgrazing, with tens of hectares of barrens occurring mostly between 20-30m depths, and in some cases in depths greater than 60 meters.

As the extent of barrens in Tasmania increases, it is widely accepted that management responses to the problem of overgrazing of kelp beds by Centro are warranted. Early actions that control the spread of Centro can prevent high levels of urchin densities from breaching tipping points and resulting in barrens. Where urchins have been removed to very low levels, recovery has not occurred. In essence, an ounce of prevention is worth a ton of cure.

Results of both extensive field experiments and sophisticated modelling are consistent and show clearly that management challenges associated with reducing the risk of ongoing destruction of kelp beds by Centro and rehabilitation of extensive urchin barrens back to kelp beds are fundamentally different problems that require different solutions.

This workshop was convened by the Department of Primary Industry, Parks, Water and Environment (DPIPWE) to consider progress with the control of Centro in Tasmania. The overall focus of the workshop was to develop a basic guidance framework for mitigating the issues and navigating the challenges surrounding Centro that can be used in the development of an action plan for urchin

[1] There are two commercial species of sea urchins in Tasmanian state waters: 1) *Heliocidaris erythrogramma* (short-spined), which is endemic to Tasmanian State waters and has well established markets, and 2) *Centrostephanus rodgersii* (longspined). The longspined urchin is a much larger species that has only recently become established in Tasmanian waters following changes to the East Australian Current and ocean temperatures. This longspined species is commonly referred to as "Centro", and represents a major threat to Tasmanian fisheries as it feeds on kelp and other marine plants, forming barrens and depriving other species of feed and habitat. For the purposes of this report, all instances of *Centrostephanus rodgersii* will be referred to as "Centro" as this is the commonly used vernacular for the invasive species, and all references to "urchins" within the report are similarly specific to *Centrostephanus rodgersii*.

management designed to halt the spread of barrens and, where possible, restore impacted marine ecosystems.

The agenda for the workshop and a list of participants are provided in Appendix 1 and 2, respectively.

1.2 Opening remarks

Ian Dutton, Director of Marine Resources, DPIPWE, opened the workshop to introduce and invite Fiona Bourne, General Manager of Water and Marine Resources, DPIPWE, to provide opening comments along with additional comments from Dean Lisson, CEO, Tasmanian Abalone Council.

The objectives of the workshop were outlined by Ms Bourne. These were to:

- Provide details of recent research on Centro distribution, impacts and control programs underway currently;
- Identify possible actions to control Centro and/or mitigate their impacts to assist funders to coordinate and prioritize response efforts;
- Identify research needs in support of Centro control strategies to assist funders and grant applicants to understand priorities in the short and longer term; and
- Propose methods to improve public understanding of the causes and consequences of the increasing abundance and range of Centro.

Dean Lisson provided remarks on behalf of the wild capture fishing industry in Tasmania that acknowledged the new Director of Marine Resources, Ian Dutton, and the DPIPWE team for putting together the forum and highlighting the importance of the issue along with the forum presenters, and the commercial industry that is generating income from Centro, through the production of roe.

1.3 Workshop format

The morning of the workshop was comprised of a range of presentations that reviewed and summarised the status of Centro and activities currently being undertaken to manage the spread of Centro in Tasmania. Experiences of urchin control methods were also presented from Victoria and Norway. The Victorian presentation summarised methods for urchin culling and harvest by divers, while the Norway presentation covered the use of calcium oxide, commonly known as quicklime, to kill urchins.

In the afternoon, workshop participants divided into break-out tables to discuss three main topics, each of which had two main themes:

i. Market Based Approaches to Centrostephanus Control
  - *Expanding markets for sea urchins and uses of urchin waste*
  - *Subsidies for urchin control*

ii. Physical Control of Centrostephanus
  - *Public engagement strategies: what might recreational divers do, where and how?*
  - *Industry engagement strategies: what strategies are best undertaken by industry, where and how?*

iii. Biological Response to Centrostephanus
  - *Top-down approaches: maximizing lobster-based control methods*
  - *Non-lobster based biological control methods, including habitat management strategies (replanting kelp, etc.)*

Table convenors reported the results of their discussions and the workshop concluded with a summary of outcomes and discussion of next steps.

1.4 Current Status of Centrostephanus in Tasmania

2017/18 Centrostephanus Survey Results – Scott Ling (IMAS) (http://ecite.utas.edu.au/129569)
The abundance of Centrostephanus and the extent of its impact on kelp beds in eastern Tasmania were re-surveyed by divers and underwater towed-video in 2016/17 and assessed relative to baselines established in 2001/02. The survey used the same sites and techniques used for the baseline coastal surveys done in 2001/02, giving a high level of confidence in results. One hundred fifty-six dive and 156 video transects spanning 13 sites were completed.
Key changes to the abundance of Centrostephanus and the extent of barrens from the survey are presented below.

	2001/02	2016/17	Change
Estimated abundance	1,200 urchins per ha	2,600 per ha	x1.75 increase
Estimated number individuals and weight (t) (4-18m depth range)	6.7 million (1,850t)	9.9 million (3,000t)	x1.48 increase (x1.62 increase by weight)
Total cover of barrens as a % of reef	3.4%	15.2%	x4.5 increase
Percentage of barrens of any type	9%	47%	x5.2 increase

Other observations were:

1) The increase in Centrostephanus has not occurred evenly. While Centrostephanus remains rare in southern Tasmania (south of Tasman Island), urchins at sites on the rest of the east coast increased from an average density of 1,495 to 2,623 individuals per hectare.
2) Barren formation has not been even across depths/habitat, with the greatest change occurring on boulder-dominated reef between 18 to 30m.
3) The only evidence for slight decline in urchin abundance is in shallow water (8-10m depth) at St Helens, which is consistent with harvesting of the urchin at this site since 2009.
4) Approximately half of reefs on the East coast (47%) are now showing signs of grazing impact, with some reefs approaching the overgrazing ‘tipping-point’ in coming years.
5) The spatial information on barrens coverage and locations at greatest risk of overgrazing as obtained during this survey will assist further targeted interventions.
6) Translocation or lobster rebuilding thus far would not affect trends in the re-survey because of timing and the requirement for lobsters to grow to large sizes (>140mm carapace length) in order to be capable of preying upon Centrostephanus.
7) There is a need for urgent action to prevent further overgrazing and loss of kelp bed resilience, i.e. an ounce of prevention worth a ton of cure.

2. Current Centrostephanus management initiatives

2.1 Harvest subsidy program update - Dean Lisson (Tasmanian Abalone Council Ltd)

First hand diver observations of expanding Centro barrens and changes in Tasmania’s rocky reef habitats led the Tasmanian Abalone Council Ltd (TACL) Board to approve the use of the Abalone Industry Development Fund (AIDF) to subsidise the commercial harvest of urchins. The Subsidy Program commenced during the 2016 Centro harvest season and has been in operation since. This assistance was also seen as a means of providing start-up funding to the fledgling Tasmanian urchin processing industry. Initially, two designated harvest areas were chosen to target incipient urchin barrens: Cape Pillar to the northern tip of Fortescue Bay in the Southeast (75% of effort) and North of St Helens (25% of effort).

Various elements of the program have been progressively relaxed since the subsidy began to include wider areas of harvest, the removal of time restrictions and making the program available to all Commercial Dive (FLCD) license holders and processing entities.

The beach price paid by urchin processors in 2016 was around $0.75/kg, and divers invoiced the TACL $0.75/kg, resulting in a total dive rate of approximately $1.50/kg. During 2017 and 2018, the price paid by processors to divers gradually increased and the TACL subsidy remained in place at $0.75/kg. The TACL has invested $150,000 in the subsidy program to date, with a further $50,000 available from a second $100,000 tranche from the AIDF. To ensure probity, the TACL retains copies of every urchin dive docket submitted by divers to access the subsidy. These dockets also provide spatial data showing where the urchins were harvested. As of early November 2018, the total weight of Centro harvested under the TACL urchin subsidy program is 200,000 kg, which amounts to about 600,000 urchins removed from between the St Helens/Bay of Fires region south to Maria Island.

Looking to the future, there is a need for experienced urchin divers to source quality roe, ideally targeting shared reefs between the abalone and urchin fisheries. The AIDF funding for the subsidy finished mid-January but has be replaced, at least initially, by funds accessed from the Abalone Industry Reinvestment Fund (AIRF) which was established at the commencement of this financial year. The AIRF is a $5.1 million fund, which is to be used primarily for abalone stock enhancement, and will likely include a component for the control of Centro.

2.2 East coast rock lobster management - Klaas Hartman (IMAS)

The Tasmanian rock lobster fishery experienced a substantial reduction in recruitment in the early 2000s resulting in a fall in biomass and historic low catch rates in the late 2000s. This reduction was experienced across all Australian Southern Rock Lobster (SRL) fisheries and remains unexplained. In response, the Tasmanian total allowable commercial catch (TACC) was reduced from 1523.5 tonnes to 1,050.7 tonnes between 2008/09 and 2014/15.

Catch rates on the east coast were substantially lower than the state average, which, combined with low percentages (about 1%) of large lobster and pressure from both recreational and commercial fishers, led to the consideration of additional management action.

Scenario testing was used to test a variety of management options including size limit changes (minimum and maximum), additional closures, translocation and catch limits (state-wide and regionally). These tests determined that the most effective way to manage rock lobster on the east coast was to restrict catch in the target (most heavily depleted) areas, thereby increasing biomass. In 2013 the East Coast Stock Rebuilding Strategy 2013-2023 was developed and implemented, with the key objective to rebuild the biomass of rock lobsters in the heavily depleted stock rebuilding zone to 20% of unfished levels by 2023, and the secondary objective to increase large lobster biomass. A combined limit of 200 tonnes for the commercial and recreational catch was set initially and remains in place.

Recreational catch fell following the introduction of the rock lobster rebuilding strategy, which included a series of bag limit changes (from originally five down to three, and now two, per person per day), and temporal closures, both of which have been maintained through to today. Commercial catches were reduced to below half of the recent 2005 peak through application of a catch cap. The substantial reduction in fishing pressure resulted in an almost doubling of the rock lobster biomass in the stock rebuilding zone. There is concern however, that higher recreational catches may occur due to increased participation as the rebuild continues. In contrast, the commercial catch is tightly controlled through a catch cap system. The expectation is that recruitment will continue to increase substantially.

Modelling suggests that numbers of large lobsters have doubled since the inception of the rebuild strategy and will continue to increase to between 1.6% (area 1) and 8.4% (area 3) of unfished levels by 2023. Due to the low proportion of lobsters that fall in this size class there has not yet been clear empirical evidence of this increase in length-frequency data (it is difficult to detect this change).

2.3 Centro harvesting and processing - John Keane (IMAS)

Since 2009 a total of 608 tonnes of Centrostephanus (> 1 million individuals) have been harvested from the Tasmanian east coast. Annual catches rose to 97 t in 2014 before decreasing to 19 t in 2015 following with the closure of the state's largest processor at the time. A new industry driven subsidy saw landings hit 188 t in 2018. Most of the catch (> 90%) is taken from the St. Helens region. If harvesting is to provide an effective management tool state-wide there is a need to distribute and/or increase catch within high-risk barren formation areas further south.

An attempt to quantify the effects of fishing pressure on stocks and habitat during 2014 – 2016 unfortunately coincided with a period of low harvest. However, on the reefs around St Helens significant declines in size and age structure of the urchin population were observed in heavily fished areas through to 2016. The emergence of large numbers of juveniles following fishing had maintained high urchin abundance in some areas, particularly around Sloop Reef. Some kelp recovery was observed within the region which resulted from fishing efforts. Resurvey of research sites, including Sloop Reef, following the current elevated harvest level would be highly informative to determine the impact of and recovery for both urchins and kelp following fishing.

Although limited in data, voluntary spatial tracking (GPS logging) of the harvest operation during this 2014-15 period indicated an approximately 50% spatial overlap with abalone fishing operations. Additional comprehensive spatial data as the industry develops would enable improved understanding of the fine-scale interactions between the urchin and abalone fisheries, as well assist efforts to determine the effectiveness of harvesting as a control measure and the overall effectiveness of subsidies.

Abalone roe is processed by grade, with the saleable A, B and C grades representing approximately 6% of the landed (wet) weight of urchins and the unsaleable D grade 3%. The remaining 91% is waste and comprises mostly tests (57%) and coelomic fluid (18%). In 2018 the urchin fishery generated an estimated 133 tonnes of waste (cost of disposal $200/tonne). Increasing yields of the more valuable roe grades developing by-products using the currently unsaleable D grade roe and waste are seen as the biggest opportunities for the harvest industry.

2.4 Culling Trial results - Craig Mundy (IMAS)

An industry (TACL) implemented, spatially discrete culling program for Centrostephanus, was undertaken in October 2012 in Wineglass Bay, Tasmania in a collaboration with IMAS. The objective was to determine the effectiveness of divers physically destroying urchins in-situ to allow for the re-establishment of native flora and fauna. The effectiveness of a follow-up cull four weeks after the initial cull was also evaluated. Cull sites were revisited one and two years later to evaluate the effectiveness of the urchin removals and the recovery of the marine habitat.

Divers accomplished almost complete culling coverage of the study area. After a 12-month period, little change was observed at the study site. Macro-algae was observed to return two years following the cull, with almost no urchins returning to the cull sites. Results from the culling program indicate that targeted culling by divers in small, discrete patches at intermediate depths is effective at reducing urchin abundance and facilitates recovery of kelp beds.

An estimate of available bottom time using Nitrox rather than compressed air for depths where extensive barrens were most prevalent demonstrated a two-fold increase in the potential number of urchins culled. During the in-situ culling program, the average cull rate was 7 urchins per diver per minute (maximum of 14 urchins/diver/minute), with an average 4.8 hours required to complete a 1,500 m^2 plot of reef (5.2m^2/minute). At a depth of 25 m, two compressed air dives allow approximately 31 minutes in total bottom time (20 minutes and 11 minutes), resulting in an approximate total of 217 urchins culled. Use of Nitrox enables more than double the dive duration, totalling 79 minutes across two dives (50 minutes and 29 minutes), with an approximate total of 553 urchins culled.

While urchin culling by divers can be highly effective, it is also a very expensive option for urchin removal and habitat recovery. The constraints imposed by safe diving limits at depths between 15m and 25m restrict this option to intermediate depths at high priority sites, as determined by fishery value, biodiversity, tourism, etc. There remains a need to determine the level of culling repetition, likely between 5 to 7 year intervals, and to identify standards required for divers operating occupationally, recreationally, or for fishing or research purposes.

2.5 AUV Robots - Craig Johnson (IMAS)

Most urchin barrens occur in the 18-40 m depth range, which can limit and/or restrict dive removal as a culling option, as divers are typically restricted to shallower depths with limited dive times. Autonomous Underwater Vehicles (AUVs) are a potential option to remove urchins at depths beyond the capacity of normal divers. A collaborative research programme between the University of Tasmania and the Georgia Institute of Technology is exploring the development and use of AUVs to remove the long-spined sea urchin in Tasmania's waters. Trials of these AUVs will be undertaken in the Sloop Rock region in February/March 2019. Trials will include assessment of the capacity of the AUV to collect data on the marine community, which will involve comparing data collected by the AUV with diver-based assessments on the same transects. The collection of data along previous dive transects will enable comparative analysis.

The AUVs under development are small, designed to operate for days at a time and use new technologies with extended battery life. The option for a vehicle to recognise when its battery is low and visit an underwater recharging station before continuing with its work is under consideration. The AUVs will include a data gathering module and image recognition technologies to not only recognise urchins, but also recognise and count abalone, rock lobster, and other organisms of interest. The AUVs also support a kill module and a navigation module. The kill module commands the AUV to punch approximately 12 mm holes in the urchins, sufficient enough to kill these organisms. The navigation module represents a significant technical challenge through its development of dead reckoning software to ensure precision navigation such that the machine sweeps through the entirety of a designated area for urchin removal. There is commercial interest in this project as multiple units will be required to kill the urchins and rehabilitate the kelp beds. Total costs and business models for the AUVs are still unknown in these early stages of development, with estimates in the low few hundreds of thousands of dollars and options to sell or lease the AUVs.

While it is clear that building populations of large lobsters in existing kelp beds will greatly reduce the risk of urchin barrens forming, and that diver-based harvesting or culling can be effective in controlling urchins in shallow water (<15-18m), removing sufficient urchins from urchin barrens occurring at depths >15m to enable recovery of kelp beds will require interventionist technologies. The use of AUVs is one such technology being considered for this task.

2.6 Assessment models for planning effective control of Centrostephanus - Katie Cresswell (IMAS)

Modelling the stock dynamics and removal strategies for Centro enables the testing of different management strategies before management actions are undertaken. Estimates of changes in biomass across locations, depths and time can be predicted, informing removal options to decrease biomass. Modelling can also identify the degree of urgency and magnitude with which different removal techniques should be applied.

Models are informed and parameterized by existing information including results from culling experiments; surveys of urchin biomass and barrens; catch and effort data from fisheries; urchin growth, movement, morphology and genetics; oceanographic information; previously conducted studies related to this issue and previous modelling efforts. Key questions and information needs remain however, and the development of models can help to inform the most important areas of uncertainty and how best to reduce this uncertainty. Key areas of uncertainty include biomass predictions and the amount of fishing effort required to effectively deplete Centro at appropriate spatial scales. Additional data, including GPS and depth tracking of commercial divers, will be required to inform this analysis.

Modelling enables the comparison of different direct removal methods of Centro, including fishing, culling, quicklime and possibly the use of AUV robots. Variables such as cost of removal, depth, reef type, urchin target size and the frequency of removal efforts can be compared, informing management of the costs and benefits of various removal options.

3. Case studies from outside Tasmania

3.1 Victorian experience with Centrostephanus - John Minehan (Eastern Zone, Victoria)

Centro is having a substantial impact on abalone habitat in Eastern Victoria in mainland Australia, with a loss of around 50% of kelp forest habitat between the NSW border and Point Hicks. Urchin biomass and barren expansion at the eastern end of the Victorian coastline has continued to increase at a similar rate to that around Tasmania, albeit from higher initial biomass levels of approximately 10,000 tons of kelp beginning in 2000. Loss of weeded reef in deeper Victorian coastal waters, and anywhere where no harvesting or culling controls exist, continues. Currently no solution is available for restoring barrens greater than 15m in depth.

While the first objective of the culling program was to prevent further loss of habitat at key abalone reefs 0-15 m in depth, it was found that it was possible to cost-effectively reverse recent damage and reclaim adjacent extensive barren habitat.

At the western end of the urchin-impacted Victorian Abalone Fishery Eastern Zone, culling by divers is used to to reduce insipient barrens and prevent extensive barren formation. This is achieved by divers sweeping across large areas of reef to target small urchin patches, and by divers targeting urchins using previously collected GPS marks. At the eastern end of the Eastern Zone, where the targeted objective is to recover extensive barrens, a more structured approach is employed, with dive quadrants carefully defined and marked by surface buoys.

When culling an extensive barren, instead of attempting to remove every urchin, divers more strategically target the higher areas of urchin densities and subsequently re-visit these barren areas each year. It is relatively easy to identify urchin areas that have been missed and which require additional follow-up attention. While the cost of restoring an extensive barren is relatively high for the initial cull, the effort and cost to maintain the area diminishes quickly over time. This strategy has been found to be cost efficient and effective.

Harvesting is another critical component of the Victorian urchin management program, and industry has been working with mainland processors to improve prices and increase the level of harvest. Wherever harvesting occurs on a consistent basis, a significant improvement in reef health through increased weed cover has been observed. While a limited subsidy is available to encourage harvesting in new locations to offset travel costs, no subsidy exists for harvesting where it is already occurring and has been proven to be financially viable. As the harvesting sector develops in

Tasmania, some concern has been expressed about the potential competitive impact of subsidised urchin product from Tasmania on existing markets for Victorian urchins.

3.2 Lessons from Crown of Thorns Starfish (CoTS) control programs - Ian Dutton (DPIPWE)

There have been four major CoTS outbreaks in the Great Barrier Reef (GBR) since the early 1960s, each lasting approximately ten years, with the most recent outbreak from 2010 still spread along the GBR today. COTs outbreaks can occur in densities up to 1,000 CoTS/ha. CoTS are voracious predators which can move up to 20 km/hr while decimating ten square meters of coral and can produce up to fifty-million eggs/year. There are no known market uses for CoTs.

From 1985 to 2012, coral cover declined in the GBR from 28% to 13.8%, as a result of impacts from tropical cyclones (48%), CoTS (42%) and coral bleaching (10%). Without intervention, coral cover in the GBR will likely fall to 5 to 10% within the next ten years. In the absence of pressures from tropical cyclones, CoTS and coral bleaching however, reefs can recover at a rate of 2.85%/year. While mitigation of global climate change and ocean acidification impacts are essential for the future of the GBR, given that mitigation is unlikely in the short term, there is a strong case for large scale direct action to reduce CoTS populations, prevent further coral losses and improve reef resilience.

Control measures for CoTS initially included manual controls such as cutting up, removing and burying the CoTS ashore, followed by lethal injections and culling by divers. Largely due to limitations in access and high costs for diver removal, CoTS control measures are increasingly moving toward newer technologies such as more efficient lethal injections and the use of autonomous underwater vehicles (AUVs). The Great Barrier Reef Marine Park Authority (GBRMPA) and Australia’s Commonwealth Scientific and Industrial Research Organisation (CSIRO) have developed a CoTS response strategy, with five key goals: 1) to control CoTS at a single site, dependent upon scale, 2) to protect assets, 3) to manage existing outbreaks, 4) to prevent outbreaks in a designated initiation box area and 5) to remove the ultimate causes of CoTS outbreaks. Public-Private Partnerships have been critical to controlling CoTS in the GBR.

Key lessons from the GBR CoTS outbreak experience that are potentially relevant to the spread of Centro in Tasmania are that the science of outbreaks is complex, and time is required to adequately plan, deploy and assess control measures. Outbreaks are typically multi-causal and synergistic with other changes in the marine environment that require multi-phase, strategic planning. Responses range from what can be done immediately, such as a focus on single urchins at single sites, to longer-term control of urchin outbreaks at all sites. Setting clear goals for research and response is essential, and funding requires public, private and political support. Effective communications are additionally critical in empowering public understanding, political support and, ultimately, in securing funding support for action.

3.3 Norwegian experience with urchin control - Hans Strand (IMR Norway)

Historically, large predators such as cod, haddock and wolffish dominated the Norwegian coastal ecosystems. Increases in fishing pressure reduced stock and sizes of these species. Herring stocks, which historically represented up to 15 million tonnes of biomass in Norwegian waters, collapsed during the 1960s. This overfishing probably resulted in a significant increase in urchin numbers beginning in the 1970s, from about halfway along the Norwegian coastline north to the Russian border. Grazing pressures by urchins rapidly transformed productive kelp forests to urchin barrens with kelp losses estimated at around 20 million tonnes of standing biomass in Norway, along with associated losses of small animals such as copepods, arthropods and snails. The loss in standing stock also represents an equivalent loss of kelp biomass production each year.

Kelp forest collapses have led to overall losses in ecosystem services, particularly in inshore areas. Once denuded, barrens have been maintained by continuously grazing urchins for decades, with some remaining in the same denuded conditions for 40 to 50 years.

Numerous options have been trialled by Norway to control urchins, including harvesting and the application of quicklime. Initial urchin harvesting trials revealed that most urchins were in such poor condition as to not contain marketable roes. To combat this problem, a Norwegian research institute developed a special feed which resulted in high quality roe within 2 to 3 months. However, roe enhancement at an industrial scale failed for economic reasons.

On the Norwegian coast the native brown crab is expanding from south to north, while the introduced Kamchatka crab is expanding from north-east to west. Predation by these species has reduced urchin numbers and led to kelp regrowth. The brown crab expansion might be density dependent and due to lack of predators while the Kamchatka crab was introduced by the Russians for commercial reasons. Their contribution to kelp regrowth is an accidental side effect. Given that urchins are probably among the least preferred food items, the use of high crab densities as a strategy for sea urchin decimation would be limited. However, in a mature kelp forest the native crab would probably be an important contribution to balance the sea urchin population.

As wolffish populations in the northern Norwegian fjords also collapsed during the 1970s, and since this mainly non-piscivore species has sea urchins as their preferred food item, it is suggested that rebuilding wolffish stocks might also be an important contribution to kelp forest resilience. In addition, since experiments have shown wolffish to be very aggressive toward the important juvenile cod predator sculpin, rebuilding the wolffish stocks might also help in rebuilding the coastal cod stocks. At the current time, however, this is a speculative suggestion.

Based on the success of the use of quicklime in removing sea urchins in California, Canada and Japan to rebuild kelp forests, this control method was trialled and further developed in Norway. Early quicklime experiments where quicklime was sprinkled on the surface showed that it was very effective in landing on, attaching to and killing urchins within minutes. Kelp re-growth on barrens that had been denuded for decades occurred within a year. Challenges remained around the distribution of the quicklime to urchins hidden under stones and in high urchin recruitment areas. Further experiments showed that finer quicklime particle sizes (smaller than 0.5-2mm), if maintained on the urchins for 2-3 minutes without being discarded by the urchins, dramatically increased mortality.

Several sceptics in Norway, particularly from the NGO and environmental sectors, were concerned about the use and impacts from quicklime due to the possibility of mortality to non-target species. Quicklime effects only last for a few hours however before the lime is turned back to harmless calcium carbonate. Application of quicklime is most effective at low tide to ensure the smallest possible distance between the sea surface and urchins and the greatest amount of contact possible between the lime and the urchins' exoskeletons. If contact is made too late, the lime can acquire a soapy, slushy appearance and can slide off the urchins. Hence, greater depths and wave action can make quicklime application more challenging for urchin control. Next year researchers will return to study sites to monitor the effects of smaller quicklime particle sizes.

In summary, the sea urchin bloom and consequent kelp forest loss in Norway was likely caused by overfishing. Liming is potentially a cost-effective and environmentally friendly urchin control method, which can be applied in efforts to rebuild kelp forests. Reactions to liming largely depend on the individual or stakeholder queried, and the style of communication.

4. Workshop session outputs

4.1 Market-based Approaches to Centrostephanus Control

There is a need for an integrated harvesting strategy for urchins to balance sustainable harvest with culling. A better understanding of the population dynamics of urchins and their ecosystem interactions will assist in achieving that balance. As harvest proceeds, there will be a requirement for GPS tracking and resurveys of urchin stocks.

4.1.1 Expanding markets for sea urchins and uses of urchin waste

Strengths of using harvest strategies and expanding markets for urchin roe include:

- a proven market, with an average of 80 tonnes taken over the last three years and an increase in landings over the last year;
- harvesting is a feasible activity that contributes to urchin removal and ecosystem restoration;
- domestic and overseas markets exist, with no significant barriers to export, noting that exporting to Japan may be more feasible;
- the tonnage harvested in 2018 (~160 tonnes) is now larger than the average increase in urchin biomass between surveys (~80 tonnes) which suggests that harvesting is successfully operating at a scale to control urchins.

The primary **weakness** has been constraint due to the limited domestic market, noting that the further development of export markets is a priority.

Developing markets and uses for non-consumption and waste:

About 90% of the urchins biomass harvested is waste, with considerable costs associated with disposal. There is potential to find uses for this waste (e.g. drying/bait etc) which should be explored.

Similarly, the quantity of inedible, D grade roe as a proportion of the total roe production is substantial. Possible uses such as for pate and oil extraction offer opportunities for alternative markets to provide a 'tipping point' to make urchin harvesting a viable economic operation.

Subsidies to promote the harvesting and processing of urchins have been used with some success for both domestic and export markets (see following section). While the TACL-driven subsidy has been opened up spatially and temporally, there is an opportunity to use subsidies to target areas for extraction.

4.1.2 Subsidies for urchin control

Strengths

- Subsidies have the potential to encourage export market development, where demand for large quantities of roe exists. These subsidies should be to provide start-up support leading to stand-alone economically viable operations. One large exporter in particular, RTS PauaCo Pty Ltd, shares this view.
- Barrens may be prevented from forming and expanding beyond tipping points through the provision of differential subsidies across zones that will focus harvesting in key areas.
- The rationale that subsidies are being applied to achieve environmental outcomes may outweigh the usual criticisms targeted at the provision of subsides to commercial operations.

Weaknesses:

- Cost; while some funding is available, there is insufficient money to rely on culling alone due to the scale of the problem.
- Gaining acceptability for subsidies/grants to be directed toward businesses remains a challenge for the limited domestic market where non-subsidised produce has to compete with subsidised produce.

Funding is limited for harvest subsides and broader urchin controls. The scale and potential severity of the issue may increase the potential for accessing Commonwealth funding. Similarly, more onus for funding could be placed on the recreational fishery and the general public such as through using a small percentage of recreational license fees to fund rehabilitation. NRM funds may be applied. Lessons can be learned from Crown of Thorns Starfish (CoTS) funding. Research and development funding may be applied, particularly towards product development.

Organisations that should be engaged in the promotion (and possible subsidy) of the urchin harvest sector include: DPIPWE, Commonwealth Government, TSIC and TACL with possible additional opportunities for engagement from pharmaceutical companies.

Research priorities include the improvement of post-harvest roe quality and commercial opportunities for urchin waste, including as fertiliser and pharmaceuticals.

4.2 Physical Control of Centrostephanus (liming, culling, robots, etc.)

4.2.1 Public engagement strategies – what might recreational divers and others do, where and how?

In addition to the suggestions for funding support and support for management strategies made elsewhere, a range of strategies is required to encourage recreational fishers to cull urchins.

Suggested strategies, which were communicated as **strengths** for recreational culling, were:

- Opportunistic/casual culling by recreational divers.
- Coordinated, targeted culling by dive clubs and individuals, including demonstrations of how best to effectively cull.
- Harvesting for consumption, including how to best to handle and prepare urchin roe.
- Harvesting for burley to attract target species e.g. snapper and other fish.
- Other uses such as garden fertilizers.

The key **weakness** is that very little information is available to recreational fishers/divers concerning the extent of the urchin problem, and how recreational fishers and divers can assist. Where divers have obtained information from websites, Facebook etc, this information has been frequently contradictory, with uncertainty over where and when (or indeed if) recreational divers should smash or harvest urchins.

- The **key challenges** will be to *Incentivise recreational fishers,* with due regard to health and safety, noting that the preferred approach of recreational fishers culling on a voluntary basis, independently, should not present a problem. Information sheets could be created to provide background information about this issue, increase overall communications, and assist in identification.
- There is a need for these strategies to ***manage the potential negative overlap with the commercial fishery harvest***, which, in the case of an uncoordinated approach, could lead to resource conflict. There is some potential to *create maps for recreational fishers*, to clearly

show areas where culling is most needed and other areas where commercial harvesting is occurring. This could be *incorporated into existing apps with hotspot areas identified where culling is needed*. Recreational divers could plot where they have culled. As this work is developed, increasing coordination will be required.

- Key **organisations** are dive clubs and interested dive shops. Government and peak bodies can also promote culling procedures. DPIPWE may outline issues and procedures for culling in the Recreational Sea Fishing Guide, and on the sea fishing web pages.

Need for **local champions or a coordinator** e.g. local dive clubs. Follow-up monitoring after culling would be useful, providing feedback and encouragement for engagement.

Low-level approaches will require limited **funding**, but more organised recreational culling events and the organisation associated with coordinating culling will require higher levels of funding. Possible incentives include grants to local dive clubs, barbecue information days and tank fill vouchers.

4.2.2 Industry engagement strategies – what strategies are best undertaken by industry and how?

Liming

- ***Strengths***: Predominantly kills off urchins, “win-win” on full-blown barrens, helps to re-establish macroalgae in systems, short term effects with limited impact on other biota, particularly given the nature of barrens.
- ***Weaknesses***: Need for research trials to be conducted to understand effectiveness in killing urchins and impacts on key species, including abalone. More difficult to apply lime in deep water using existing technology, new methodologies are required. Unknown appetite from government and the community for the use of lime to control urchin populations. Unlikely to be a ‘quick fix’ given the trials needed and permissions required to be obtained.

Culling

- ***Strengths:*** Targeted. Capacity to target areas of high value/production and thereby prioritise culling activities. Potential for collaboration with other sectors e.g. rec sector, and to be rolled out in the short term. Considered highly environmentally friendly.
- **Weaknesses**: Resource-intensive, and some uncertainty about long-term funding to support culling. Potential conflict with commercial harvest for roe production. It was noted that culling does not fall under a fishing activity in the Fisheries Act, so if paid culling is an option may need to comply with AS 2299 rather than the Abalone Diver Code of Practice if fishing (taking).

Harvest

- ***Strengths:*** Controlled and eco-friendly.
- ***Weaknesses****:* Likely to be subsidy-reliant, at lease in initial stages. Potential to be affected by changes in government, and changes in policies regarding access. Dumping of product on local market likely to affect prices.

Concept of a bounty vs subsidy was also discussed to allow more targeted effort in some areas.

ROVs:

More research needed, but a possibility to continue to consider when more information on costs and feasibility are obtained. Substantial funding will be needed to support this approach.

4.3 Biological response to Centrostephanus

4.3.1 Top down approaches – maximising lobster-based control methods

The rock lobster assessment model is relatively mature, well understood and demonstrated to provide effective predictions of rock lobster biomass. The holistic ecosystem models that include not only rock lobster, but also abalone, urchins and kelp, and their interactions are becoming increasingly refined, but these products are less well developed.

Additional research to support ecosystem models is required to:

- Better understand the implications of rebuilt rock lobster and abalone populations, and better understand rock lobster predator-prey relationships (e.g. as the abalone biomass increases, do urchins fall lower on the chain for preferred rock lobster prey and therefore become less targeted?). A PhD topic with associated support is now advertised on the IMAS website and, if filled taken up, will provide information on rock lobster prey preferences in a multi-choice context.
- Expand knowledge of the extent of barrens on the east coast, which are driven by a dated habitat mapping dataset. New data on reef complexity and bathymetry needs to be generated using modern technologies including multi-beam or side-scan sonar between 5m and 40m.

The key **strength** of using rock lobster as a control method is that once stocks are rebuilt to a target level, the population can maintain itself indefinitely, provided adequate recruitment occurs and fishing mortality is adequately constrained. There is no need for reinvestment in this control method and, provided spatial management tools are introduced, higher priority areas can be spatially targeted.

The key **weakness** of rock lobster management efforts based on model predictions is that modelling is done on a coarse scale that assumes a homogenous population of rock lobsters and urchins. There have been calls for spatial management of rock lobster populations to address this issue, and to enable targeted relief of fishing pressure at local scales where urchin abundance is high.

Additional management options using rock lobster as a control were:

- to introduce maximum size limits;
- to identify high priority and most "at risk" areas to target for translocation and rehabilitation of rock lobsters; and
- to refine lobster biomass targets that will halt or reduce barren spread and formation, which will be a function of an acceptable level of urchin barren and probability. A wider discussion regarding an acceptable level of barren coverage and associated rock lobster biomass needs to occur with stakeholders.

Key organisations that need to be engaged in the process of rock lobster control are the Tasmanian Rock Lobster Fishermen's Association (TRLFA) and its members the Department of Primary Industries, Parks, Water and the Environment (DPIPWE) and the Institute of Marine and Antarctic Studies (IMAS, University of Tasmania). There are implications of rock lobster management for both the commercial and recreational sectors and there is a need to be precise about the reasons for regulating these sectors. The estimated cost burden to specific sectors of further regulation of lobster fishing pressure must be acknowledged and considered.

Funding for further research on the use of rock lobster as a control mechanism should emphasise "efficiency, effectiveness and equity", and whether any further restrictions on lobster fishing are tolerable.

4.3.2 Non-lobster based biological control methods, including habitat management strategies (replanting kelp, etc.)

Habitat modification and kelp restoration: without the removal of urchins, restoration of kelp beds through planting is unlikely to have an impact and may simply provide nutrition for urchins.

Marine Protected Areas (MPAs) are not seen as a broad-scale solution to controlling urchins but can provide utility as reference areas. However, the use of spatial management measures for rock lobster and abalone fisheries may allow for targeted control measures of particularly vulnerable and/or impacted coastal areas.

Other control methods include introducing a biological control agent such as disease via a species-specific pathogen and relocation or re-building of natural predators (e.g. large rock lobsters and some fish species). Due to the challenging biosecurity implications of importing a disease, and because there are no known urchin diseases, *this control method is considered impractical*.

Research is required to better understand the ecological interactions of the range of scalefish, including wrasses, and the potential ecosystem benefits of restored scalefish stocks.

Totality of predators in systems is important and management action may be necessary to regulate species other than rock lobster to build overall resilience in kelp beds. As an example, it is illegal to take eastern blue grouper in Victoria and Tasmania.

Cryptic interactions are poorly understood – i.e. the ecological interactions with small urchins in rocky habitats. However, the benefits of research to understand such interactions was questioned on the basis that no additional management levers to pull in that space have been identified.

5. Trade-offs between management options

To effectively manage and control existing, developing and potential Centro barrens and build kelp bed resilience, multiple strategies will be required, based on an integrated and strategic approach that includes work to:

i) Rebuild predator stocks, particularity nocturnal-feeding larger lobsters >140mm in carapace length, but also fish (e.g. wrasse, blue groper); and

ii) Remove urchins through culling and harvest.

Approaches will need to vary from shallow to deep water, and from north to south along the Tasmanian coastline, with different solutions catering for different ecological circumstances. Cost-benefit analyses based on modelling will assist in this regard. Scott Ling's presentation from the Forum included the following table, which illustrates his view of the various urchin control strategies that need to be considered as urchin management and control efforts are progressed.

	Control option	Prevention (kelp bed resilience)	Cure (recovery of barrens)	Depth range	Est. cost per ha	Cost per 500 ha
1	Biological control - predation by enhancing large lobsters	Yes	No	0 - 40m +	Translocation/ social costs	Translocation/ social costs
2	Biological control - predation by enhancing Blue Grouper	Yes	?	0 - 40m +	Translocation costs	Translocation costs
3	Abalone/ rec. divers culling urchins while fishing	Yes	No	0 - 18m	Cost neutral	Cost neutral
4	Harvesting of urchins+ ranching to improve marketability	Yes	No	0 - 18m	Market development costs	Market development costs
5	Dedicated urchin culling by commercial divers/ rec. divers	Yes	?	0 - 18m	$18 K	$9 M
6	Autonomous robotic culling	?	?	?		
7	Quick-liming (diver/ ROV for deeper water)	?	?	?		
8	Bio-tech control (triggering disease outbreak on barrens?)	?	?	?		

6. Communication and raising awareness

All break-out groups highlighted the need to improve communication and raise awareness of the spread of Centro in Tasmania, along with the various efforts to control the spread of urchin barrens on the Tasmanian east coast. The main targets for improved communications should include:

- The general Tasmanian public;
- Fisheries Advisory Committees (FACs) for the recreational fishing, rock lobster and abalone sectors;
- State and Commonwealth Governments;
- Non-governmental organisations (NGOs), particularly environmental NGOs; and
- Consumers at the point of sale.

Communication strategies will employ a variety of fora including websites, social media such as Facebook and media releases.

Activities requiring specific communication strategies include:

- The **rock lobster rebuilding strategy**, to promote its benefits and progress toward achieving the desired increased level of rock lobster biomass, and to achieve greater understanding of and commitment to this strategy among relevant stakeholders;
- **Product harvesting**, to promote and develop markets both domestically and overseas;
- **Product development**, to promote interest in urchin waste and D grade urchin roe, including through the Australian Food Waste CRC;
- **Culling,** to promote targeted and appropriate levels of recreational culling, and to avoid negative interactions with the harvest sector;
- **Liming,** to allay unfounded fears on the impact of liming, provided trials demonstrate liming to be effective and non-detrimental to other, non-target species;
- **General public awareness,** to increase understanding of the Centro issue, and gain perspective on the extent of the problem including efforts underway to mitigate and control the spread of Centro, plans to reduce further losses of kelp forest habitat to barrens and, in the longer term, efforts to restore weed cover on barrens; and

- **Funding,** by promoting the significance of Tasmania's east coast marine ecosystems and the benefits of early, comprehensive action to increase the likelihood of additional funding sources including from the Commonwealth.

7. Next steps

The **abalone industry (TACL)** would like to see two key outcomes from the forum:

i) A strong push from the State government, led by DPIPWE, to declare the work on urchin control a "project of state significance", given that the creation of barrens is a serious ecological event that affects biodiversity, tourism, and the commercial and recreational fishing sectors. Emphasis should be placed on early, preventative actions designed to prevent kelp forest areas from being converted to urchin barrens, which, once established, will be difficult and cost-prohibitive to recover.

ii) A Coordinated approach from Tasmanian senators to lobby for matching Commonwealth funds.

Forum participants agreed that a designated entity or individual is required to lead and maintain these efforts, particularly in achieving the funding goals required for this work.

TSIC has developed a high priority policy platform that focuses on engaging local and federal politicians to support urchin management on Tasmania's east coast. Collaborative efforts between TSIC and TACL could ensure a more complimentary and communicative approach as future work is progressed on this issue.

Establishing clear objectives for addressing Tasmania's urchin issue will ensure stakeholders are clear on specific targets for urchin management. Such objectives might include *aims to slow or stop the spread of barrens, and/or to recover large areas of barrens through an extensive restoration programme*.

DPIPWE suggested the following steps going forward, for:

- The knowledge, experience and perspectives shared from the forum to be assembled into a report for circulation to participants and use by DPIPWE as a background document which can be used to communicate with key stakeholders and plan a more comprehensive response to the urchin issue. DPIPWE will be developing a strategy document that draws from materials and priorities identified this workshop to guide their response strategy;
- FACs to include a standing agenda item on urchin management, and the ongoing efforts to address the spread of barrens and related habitat restoration; and
- All stakeholders to apply a systematic and prioritised approach in addressing Tasmania's Centro issue; one that employs multiple objectives and a range of small scale and large-scale approaches in different areas as required.

TACL suggested the outcomes of the Forum should include:

- Using Katie Cresswell's modelling work to explore the costs and benefits of various urchin management options;
- The development of a business strategy/plan with State and industry commitments, for presentation to the Commonwealth, that highlights funding gaps and opportunities for contributions from the federal government; and
- Emphasis on the importance of increased public awareness of the Centro issue. TACL expressed that now is the time to elevate the urchin issue beyond the perception that its key impacts are only on the abalone and rock lobster fisheries. TACL further highlighted a need

to promote public perception of the Centro issue as a “biodiversity crisis” on the Tasmanian East Coast, with the potential for substantial and widespread impacts on the tourism industry, recreational and commercial fisheries, marine ecosystems and biodiversity.

Additional comments from the floor included:

- Recognition of the demand for this forum for some years now, noting that its successful completion is a significant and important step forward in addressing the Centro issue in Tasmania. The Director of Fisheries is to be congratulated on convening the meeting;
- The importance of regular, continued meetings about the Centro issue in Tasmania to ensure all stakeholders are aware of the progress on urchin management;
- The importance for all FACs, industry bodies and other interested organisations to be provided with the same information to ensure common understanding; and
- While the benefits of Commonwealth funding and the establishment of a major integrated project are clear, there is a need to ensure that short-term, strategic interventions continue.

DPIPWE agreed that the Forum would reconvene within the next year with an expanded stakeholder group and asked that the audience consider appropriate scheduling and participants for the next form. The next forum will provide both the opportunity for feedback on progress with the Centro response and enable DPIPWE to obtain further guidance and input on the comprehensive urchin management strategy that DPIPWE will be working on in Q1 2019.

Appendix 1 Agenda

Agenda

8:45 am – 9:15 am	Registration and Coffee	Vicki Waters (DPIPWE) Katrina Edwards (DPIPWE)
9:15 am – 9:30 am	Introduction and Welcome	Fiona Bourne (DPIPWE) Dean Lisson (Tas Abalone Council)
9:30 am – 10:00 am	2017/18 Centrostephanus Survey Results	Scott Ling (IMAS)
10:00 am – 10:20 am	Rock Lobster Harvest Strategy	Klaas Hartmann (IMAS)
10:20 am – 10:30 am	Q + A with speakers	
10:30 am – 10:40 am	***Morning Tea***	
10:40 am – 10:50 am	Harvest subsidy program update	Dean Lisson (Tas Abalone Council)
10:50 am – 11:05 am	Centro harvesting progress to date	John Keane
11:05 am – 11:15 am	Culling Trial results	Craig Mundy (IMAS)
11:15 am – 11:25 am	AUV Robots	Craig Johnson (IMAS)
11:25 am – 11:35 am	Assessment models for planning effective control of Centro	Katie Cresswell (IMAS)
11:35 am – 11:45 am	Victorian experience with Centrostephanus	John Minehan
11:45 am – 11:55 am	Lessons from Crown of Thorns Starfish control programs	TBA (GBRMPA/CSIRO to confirm)
11:55 am – 12:25 pm	Norwegian experience with urchin control	Hans Strand (IMR Norway)
12:25 pm – 1:15 pm	***Lunch***	
1:15 pm – 1:30 pm	Workshop Topic Introductions	Ian Dutton (DPIPWE)
1:30 pm – 2:40 pm	Workshop Breakouts (see below)	Various
2:40 pm – 3:40 pm	Groups present outcomes	Various
3:40 pm – 4:00 pm	Summary, Next Steps and Close	Ian Dutton (DPIPWE) Ian Cartwright (Consultant)

Appendix 2 Workshop Participants

Name	Organisation
Neil Macguffie	Abalone Victoria
Darvin Hansen	AbFAC
Jillian Freeman	AbFAC
Paul Richardson	AbFAC
Rich Little	CSIRO
Daniel Gledhill	DPIPWE
Fionna Bourne	DPIPWE
Grant Pullen	DPIPWE
Greg Ryan	DPIPWE
Hilary Revill	DPIPWE
Ian Dutton	DPIPWE
Jack Saward	DPIPWE
James Parkinson	DPIPWE
Katrina Edwards	DPIPWE
Matt Bradshaw	DPIPWE
Rod Pearn	DPIPWE
Sally Williams	DPIPWE
Vicki Waters	DPIPWE
Will Hansen	DPIPWE
Josh Fielding	FRDC
Caleb Gardner	IMAS
Craig Johnson	IMAS
Craig Mundy	IMAS
Jeremy Lyle	IMAS
John Keane	IMAS
Katie Cresswell	IMAS
Klaas Hartmann	IMAS
Neville Barrett	IMAS
Oliva Johnson	IMAS
Paolo Campus	IMAS
Scott Ling	IMAS
Hans Strand	IMR - Norway
John Ramsden	Ralphs Tasmanian Seafoods
Simon Leonard	Ralphs Tasmanian Seafoods
Adrian Hales	RecFAC
James Cartwright	RecFAC
Max Kitchell	RecFAC
Colin Buxton	Southern Rock Lobster
Mark Nikolai	TARFish
Alan Gray	Tasmanian Abalone Council
Avril Brown	Tasmanian Abalone Council
Ben Cobbing	Tasmanian Abalone Council
Byron Ransom	Tasmanian Abalone Council
Dean Lisson	Tasmanian Abalone Council
Jeremy Huddlestone	Tasmanian Abalone Council
Joey McKibben	Tasmanian Abalone Council
Jon Bryan	Tasmanian Conservation Trust Inc
Peter McGlone	Tasmanian Conservation Trust Inc

Name	Organisation
Renison Bell	TCDA
Tom Chadwick	TCDA
Rob Rattray	TRFLA
Clive Perryman	TRLFA
John Sansom	TRLFA
Julian Harrington	TSIC
Lindsay Newman	TSIC
Ian Cartwright	
John Minehan	
Kelsey Richardson	
Steve Crocker	

Tasmanian Government

Department of Primary Industries, Parks, Water and Environment
1 Franklin Wharf
Hobart TAS 7000
P (03) 6165 3000

www.fishing.tas.gov.au