Seacare
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Marine
Environmental
Systems

Restoration of String Kelp (*Macrocystis pyrifera*) habitat on Tasmania's east and south coasts.

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for Seacare Inc
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AUSTRALIA
Natural Heritage Trust
Helping Communities Helping Australia
A Commonwealth Government Initiative

FISHERIES
ACTION PROGRAM

SUMMARY

In 1997, Seacare Inc was formed by a group of people with an interest in the marine environment with the intention of facilitating community projects to address problem areas. The primary project adopted by the group related to the string kelp *Macrocystis pyrifera*. Concern had been raised over the state of *Macrocystis pyrifera* forests in Tasmania due to the perceived loss of the alga around the Tasmanian coastline. The alga is thought to be comparatively highly productive and provides food and shelter for a wide range of animals and plants.

Three lots of funding over five years were received through Fishcare, a subsidiary of the National Heritage Trust (NHT). The first project looked at re-establishing *Macrocystis pyrifera* in the upper reaches of the Derwent Estuary (NHT 1997/98). The second phase (NHT 2000/01) looked at whether or not the introduced macroalga *Undaria pinnatifida* may be a factor in affecting *Macrocystis pyrifera* re-establishment in the Mercury Passage on Tasmania's east coast. Funding was later given to continue this work and to extend it to more wave exposed coasts and in deeper waters (applied for 2001/02).

Objectives

of these projects included:

- Seminars to interested groups and volunteer coordination
- Informed site selelection in the Derwent, Mercury Passage and East Tasmanian coast
- Site assessments and stocktakes
- Site preparation
- Site monitoring
- Transplanting - reforestation
- Project progress assessment
- Development of education materials - and communication of results
- Research suitable GIS data from old charts, aerial photos, past surveys and anecdotal evidence of veteran fishers and divers for *Macrocystis* distribution.
- Request for information from the public.

- Initiate *Macrocystis pyrifera* culture at the Marne Discovery Centre at Woodbridge

***Macrocystis pyrifera* surveys**

The review of *Macrocystis* distributions dating from the early 1950's to the present, from available surveys showed that lineal extent of *Macrocystis* beds along the east Tasmanian coastline has remained relatively constant except for an anecdotal survey period between 1987/89. On a local level in some areas the amounts of the alga reflect these overall survey results, such as in the vicinity of the Southport.

There are other sections of coast that have beds that are very variable in size from year to year, in particular the area from Georges Rocks in the north east, south to Schouten Island. Large beds noted in the survey conducted in 1999 off Friendly Beaches and Ansons Bay, for example, were not present a few months later. Their demise is believed to have been coincident with large easterly swells.

In the area around the Mercury Passage, there appears to have been a decline in the quantities of the alga compared to earlier surveys. Anedcdotally, the upper reaches of the Derwent Estuary in the vicinity of Lindisfarne had lush beds of *Macrocystis*.

There are many factors postulated for the alga's decline in such areas including**:**

- Sediments on the reefs
- increase in boat traffic which cuts off growing fronds
- the over-fishing of rock lobster which are believed to feed on sea urchins. This has led to an increase in sea urchins which then feed on *M. pyrifera*
- the commercial harvesting of String Kelp have also been put forward as potential reasons for the declining populations.
- the recent introduction of *Undaria pinnatifida* (a Japanese seaweed thought to have introduced through ballast waters) which occupies a similar ecological niche to *M. pyrifera* and is thus a potential competitor
- there are strong indications that M. pyrifera populations have been declining in conjunction with the warming of coastal waters

Factors making it difficult to determine if overall levels of *Macrocystis pyrifera* are declining include:

1/ the apparent ready regeneration of *Macrocystis* beds at a number of sites simultaneously in areas where there had been none previously for long periods. This suggests that the alga may be dormant in areas where none is apparent, possibly in the microscopic gametophyte stage.

2/ the close similarity between the two species of *Macrocystis* in Tasmania; *M. pyrifera* and *M. angustifolia* and the question of how these two species may be related if at all. *M. angustifolia* appears to be becoming more prevalent in areas where *M pyrifera* is now. Is *M angustifolia* an ecological variant of *M. pyrifera*? If not is *Macrocystis pyrifera* disappearing at a rate much greater than is currently being detected?

Seacare reaforestation

A number of methods for reaforestation were trialled by Seacare for reestablishing *Macrocystis* beds, these included:

1/ transplanting juvenile plants from healthy donor sites.

2/ Transplanting fertile sporophylls (spore producing part of adult plants) to recipient sites

3/ Culture of spores in the laboratory. This has been achieved by involving the Marine Discovery Centre at Woodbridge. Students at the Centre have been involved in releasing spores from plants and culturing them up to 0.5 cm long. These are then planted at the sites.

4/ Transferring rope inoculated with *Macrocystis pyrifera* from beds with *Macrocystis pyrifera* to areas to other areas. Lines have been placed on the reef bottom in the vicinity of healthy plants. These are then transplocated to areas where there is little *Macrocystis pyrifera* to reinitiate plants.

Derwent Estuary

In the Derwent trials, preliminary surveys of existing biota revealed that there is an increase in sediment on the reefs and in salinity variation but a decrease in wave exposure and maximum depth of the reefs with distance up the estuary

Over 90 species of algae, invertebrates and fish were recorded from the surveys. Biodiversity, as measured by the total number of species detected on the transects is greatest in the moderately wave exposed locations, part way up the estuary. There is a sharp drop in number and compliment of species from Tranmere northwards up the river.

Algae

Species indicative of the more wave exposed locations are Cray Weed (*Phyllospora* comosa) and Strap Weed (Lessonia corrugata). In the upper, more sheltered part of the estuary are the green algae: Sea lettuce (*Ulva* spp.) and Dead Mans Fingers (*Codium* spp) and filamentous reds, greens and browns.

Fish

Wrasse and stingarees are very common species in the more wave exposed locations. In the more sheltered locations there are threefins and gobies.

Invertebrates

Species in the more wave exposed locations include crinoids; under rocks and in crevices and the black lipped abalone (*Haliotus rubra*). In the more sheltered locations are the introduced species the Japanese starfish; *Asterius amurensis* and the New Zealand starfish; *Pateriella regularis*.

Reefs in the upper part of the estuary are impacted as evidenced by silt on the reefs, and the presence of introduced species which are good colonizers of disturbed environments. Algae found in the upper areas of the estuary are indicative of freshwater influence and nutrient enrichment. Reef communities at the mouth of the estuary relatively pristine.

One hundred *Macrocystis pyrifera* juveniles were planted at each of these sites: Lindisfarne Point, Rosny Point, Tranmere reef, White Rock, Glenvar Bay, and Black Jack Reef with plants from Blackman Bay (Sth) over the years 1998-2000. Plants were also grown at the Marine Studies Center and placed at each of these sites.

The greatest survival and recruitment success was achieved at Black Jack Reef, where there is now a small thriving population. There has also been limited success at White Rock, Tranmere and Glenvar Bay. These sites are all closest to the mouth of the estuary. Exposure to wave action may be assisting their success however. Factors due to the river such as silt on the reefs, toxicants and salinity variations, which increase with distance up the river cannot be ruled out as adversely affecting populations.

Mercury Passage

In the Mercury Passage, the aim was to see if the introduced seaweed, *Undaria pinnatifida* was preventing re-establishment of String Kelp (*Macrocystis pyrifera*). Survival of the *Macrocystis* was very poor, but sites with urchins removed had the best success. Plants obtained from Primrose Sands rather than Southerly Bottom and Friendley Beaches also proved to be the most successful, ie. the donor site made a difference to the results. No subsequent recruitment has been evident at any of the sites in the Mercury Passage despite the varying methods of introducing *Macrocystis* to each of the sites.

Surveys of biota at the Mercury Passage sites showed that the urchin cleared areas have resulted in prolific growth of native algae. These areas subsequently have greater numbers of invertebrates such as abalone and *Comanthus* sp. (feather stars).

As there has been very limited success in reestablishing the *Macrocystis pyrifera*in the Mercury Passage with or without *Undaria*, it has not been possible as a result of this program to determine if *Undaria* may be inhibiting return of *Macrocystis pyrifera*.

The Seacare *Macrocystis pyrifera* transplant trials in the Mercury Passage had been done in urchin barren areas without a lot of success. Some plants have survived, but only in areas where urchins have been cleared. To increase our chances of success, new sites were selected again in areas where there has been *Macrocystis pyrifera* historically but in more wave exposed waters where there are fewer urchins and there is likely to be greater nutrient availability.

East Tasmanian coast *Macrocystis* transplants

Three sites were chosen: Point Home, Hell Fire Bluff and Cape Paul Lemenon. Cape Paul Lemenon in particular was the area noted by Alginates (Australia) P/L as being where 10% of all *Macrocystis* they harvested in 1970/71. There was no *Macrocystis* prior to these transplants and there has been none there as long as members of Seacare are aware (since the early 1980's). Preliminary results suggest Cape Paul Lemanon as the most successful Seacare transplant site so far with good survival of transplants as well as very strong recruitment of new plants.

Again, the results show that plants from Dodges Ferry are most successful for use in transplants. However some of the plants obtained from this site, when mature showed *M. angustifolia* characteristics of flattened holdfasts.

Transplants into deeper waters (11m rather than 6m) proved to be most successful.

However, for most surviving transplants, the surviving plants were stunted. This has occurred consistently across many transplants in different areas. This may be due to the time of planting. If nutrients are low, this may result in stunting of growth. No mention of this occurring elsewhere has been found in the literature.

The transplant method showing best results in terms of recruitment was the transplant of plants from Primrose Sands. As they are more mature, their sporophylls seeded the immediate areas and gave rise to healthy plants.

Overall

Overall, 2046 juvenile plants were transplanted (with no apparent impact on donor sites). At least 8 separate cultures were distributed across the recipient sites. In the Derwent, silt on the reefs was suggested as being the limiting factor for *Macrocystis* reestablishment. In the Mercury Passage, the urchins were the limiting factor (in addition to warm nutrient depleted waters and on the open east coast, Macrocystis may find it difficult to reestablish in areas such as Cape Paul Lemenon due to the lush growth of other native algae such as *Ecklonia radiata* and *Phyllopsora comosa*.

Volunteers

Volunteers have been involved in all aspects of Seacare activities but primarily divers were used mainly to collect the *Macrocystis* plants from the donor sites, and plant at recipient sites.

The program for re-establishment of *Macrocystis* at all sites was labour intensive and the working environment difficult. Factors working against the use of volunteers working in and on the sea for this project included:

1/ time limited: most amateur divers are limited to one SCUBA tank dive/day.

Thus at the depths we were operating, this is usually less than 1.5 hours.

2/ cold: often inadequate protection from the cold and sometimes adequate protection allowed limited time underwater. Even the surface, working in the boat, cold temperatures also limited contributions of volunteers and tested enthusiasm.

3/ although 'volunteering' many amateur divers spent part of their time underwater foraging either for abalone or crayfish - further limiting their contribution.

4/ after spending one or two times many volunteer divers had 'been there and done that' and went off and did other things.

5/ the vagaries of the weather made it difficult to predict dive dates especially for the last part of the project, which was particularly exposed to wind and swell. This made it difficult to maintain volunteer enthusiasm.

6/ Working in water has its own set of difficulties. Amateur divers often have difficulty working in the medium which takes time to overcome even before they can concentrate on the task at hand.

7/ Because of the above difficulties, training of divers was problematic as there was minimal continuity and when in the water there was little time.

8/ Many of the divers due to lack of experience were a safety risk, this meant dive supervisors had to watch on them rather than contribute in other more relevant areas.

There was an emphasis by Seacare on the achievement of objectives stated for the project and these turned out to be fairly ambitious. This necessitated only using volunteers in tasks that involved minimal skill levels. There was not enough time allocated within the project to train volunteers in tasks that required moderate skill levels.nor many volunteers had sufficient time and perseverance.

Another major problem was the issue of insurance for the volunteers involved. Seacare operated under the belief that if the volunteers were involved with SCUBA diving clubs while diving for Seacare, then they would be covered under the banner of national insurance (NAUI). This however was never confirmed.

Only a few volunteers were maintained for the duration of the project. Many came once or twice for the experience and then dropped out. This complicated the training process for the transplanting. Achievement of objectives relied heavily on the hands on approach of the project supervisor and assistant.

The project was successful in better informing the public re marine issues, particularly with regard to *Macrocystis*. Products of the three projects included a training video for *Macrocystis* transplanting, a handbook for transplanting and a handbook for *Macrocystis* culture, seminars, stories aired on television, magazines and Fishing Today.

The most successful component of community participation in the project was the involvement of the Marine Discovery Centre in growing the young *Macrocystis* juveniles. This was used as a component of the aquaculture course at the Centre and attracted a number of students. The Culture Handbook has proved to be a boon, easy to follow for culturing *Macrocystis*. Interest has been expressed from a number of schools in adopting it as part of their curriculum.

Future projects

1/

Follow up of current transplant sites should be conducted to determine if recrutment hd been successful from previous transplant programs.

2/

At the Mercury Passage sites, regular video at set locations was conducted. This provided graphic evidence of the effect of manipulating environmental conditions such as removal of urchins. The sites were within urchin barren areas and are likely to have been caused as a result of overfishing of rock lobster. Much interest has been expressed by the Tasmanian Amateur Fishing Association in 'adopting' an area of coast between Rheban and Johnsons Point in the Mercury Passage with the intent of closing the reef to all fishing and then conducting fish downs of urchins from the barrens. The urchin barrens constitute the majority of the reef area between these two sites.

The area could be monitored by biologists and changes to biota determined. Changes should include recovery of macroalgae, and invertebrates such as rock lobster and abalon.

Fish species and number should also increase. If the area was closed to fishing, the reefs may attain some sort of balance akin to their original state fifty or more years ago. This would be good evidence for the value of marine reserves in preserving Tasmanian flora and flauna and determining the effects of fishing.

CONTENTS

Chapter 1

Restoration of String Kelp (*Macrocystis pyrifera*) habitat on Tasmania's east and south coasts.

A Seacare Inc initiative

INTRODUCTION

With the extension of the Natural Heritage Trust (NHT) to include the marine component Fishcare in the late 1990's, Seacare Inc was formed by a group of people concerned at the state of the marine environment with the intention of facilitating community projects to address problem areas. The primary project adopted by the group related to the string kelp *Macrocystis pyrifera*. Concern had been raised over the state of *Macrocystis* forests in Tasmania due to the perceived loss of the alga around the Tasmanian coastline. The alga is thought to be comparatively highly productive and provides food and shelter for a wide range of animals and plants.

The projects followed positive results from earlier projects at the University of Tasmania examining growth of *Macrocystis pyrifera* at two sites on Tasmania's coast (1984-1987, Sanderson 1992) and a Fisheries Research and Development Corporation (FRDC) funded project looking at establishing *Macrocystis* forests as feed for urchins (1993-1996, Sanderson *et al* 1996). Urchin divers believe the best urchin come from *Macrocystis* forests.

The first phase undertaken by Seacare Inc (applied to NHT 1997/98) looked at reestablishing *Macrocystis* in the upper reaches of the Derwent Estuary. The second phase (applied for 2000/01) looked at whether or not *Undaria* may be a factor in affecting *Macrocystis* re-establishment in the Mercury Passage on Tasmania's east coast. Funding was later given to continue this work and to extend it to more wave exposed coasts and in deeper waters (applied for 2001/02).

The following summarizes the objectives of each of these projects.

Objectives

PROJECT 1

Restoration of Marine Habitat in the Derwent (97/98)

- Seacare committee organized
- Seminars to interested groups
- Site selection in the Derwent river for planting
- Site assessments and stocktakes
- Site preparation
- Site monitoring
- Transplanting - reforestation
- Project progress assessment
- Development of education materials - and communication of results

PROJECT 2

Reclamation of *Macrocystis pyrifera* habitat in reef infestations of introduced algae *Undaria pinnatifida* (1999 - 2000).

- Select sites in the Mercury Passage
- Set up the sites, reforest and ongoing monitoring
- Set up sites in Bellerive Bluff and Lindisfarne Point. Transplants and monitoring of these sites
- Research suitable GIS data from old charts, aerial photos, past surveys and anecdotal evidence of veteran fishers and divers.

- Request for information from the public.
- Initiate *Macrocystis* culture at the Marne Discovery Centre at Woodbridge

<u>PROJECT 3</u>

Continuing :- extension of project to the open coast (2001 - 2002).

- Select sites in the Marion Bay, Hellfire Bluff and Point Home areas.
- Set up these sites, reafforest and ongoing monitoring
- Monitoring of sites already reaforested at:
    - 1/Bellerive Bluff, Lindisfarne Point
    - 2/ Oppossum Bay, Blackjack Reef, Tranmeere and White Rock.
- Extend educational material and promotion al work including website development.
- Extend current trials of *Macrocystis pyrifera* mariculture at the Marine Discovery Centre.

Initial *Macrocysti*s eaforestation was conducted in the Derwent Estuary. Later reaforestations occurred on the east coast. The following maps (Figs 1.1 - 1.4) show the sites mentioned in the text.

This Seacare initiated program has involved volunteers and contributions from a wide variety of people and organisations. These include:

Dive clubs

Tasmanian Sub-Aqua Club
Tasmanian Marine Naturalists
Crabs
Leven Dive Club
University Dive Club

Other clubs and community organisations

Binalong Bay Coast Care group
River Keeper

Seacare donors

Pasminco Ltd

Stormy Seas Pty Ltd

Fletcher Challenge Ltd

Hobart Ports Corporation

Sanderson & Associates

Nat Murphy

Mures Restaurant

Fish Frenzy

Princess Malakov Trust

Installed Logic Pty Ltd

Peter Johnston Pty Ltd

Double B Signs

Dave Hanson Enterprises

Wattyl Paints

The Dive Shop

Glenorchy City Council

Hobart City Council

Aqua Scuba

Hunter Products

Tasfuel

Tassal Ltd

Whatsinaname

Wrest Point Casino

Stallards Camera House

Marcom Watson

Sandy Bay Sailing Club

Tasmanian Sea Urchins

Seacare stalwarts

Will James
Adele Fletcher
Sam Ibbott
Craig Sanderson
Simon Firth
Carolyn Firth
Adam Christ
Jacqui Foster
Mic Baron
Hans Benisch
David Dowell
Dave Turner

Figure 1.1 Map showing overall perpective of Seacare Inc reaforestation programs in Tasmania (1997- 2002). Green dots are recipient sites for *Macrocystis* plants. Red stars are donor sites and blue squares are control sites.

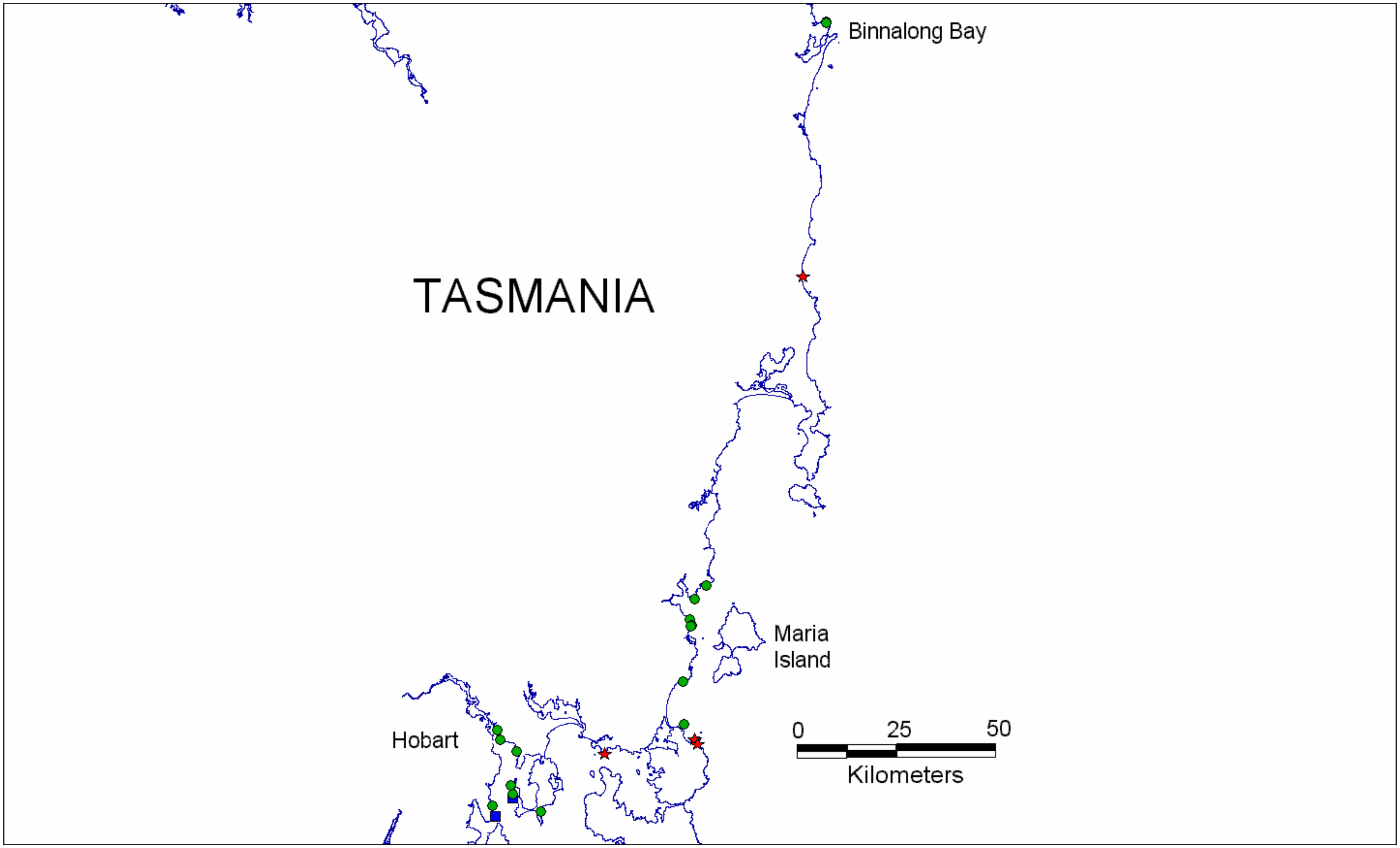


Figure 1.2 Map showing Mercury Passage Seacare Inc sites. Green dots are recipient sites for *Macrocystis* plants. Red stars are donor sites and blue squares are control sites.

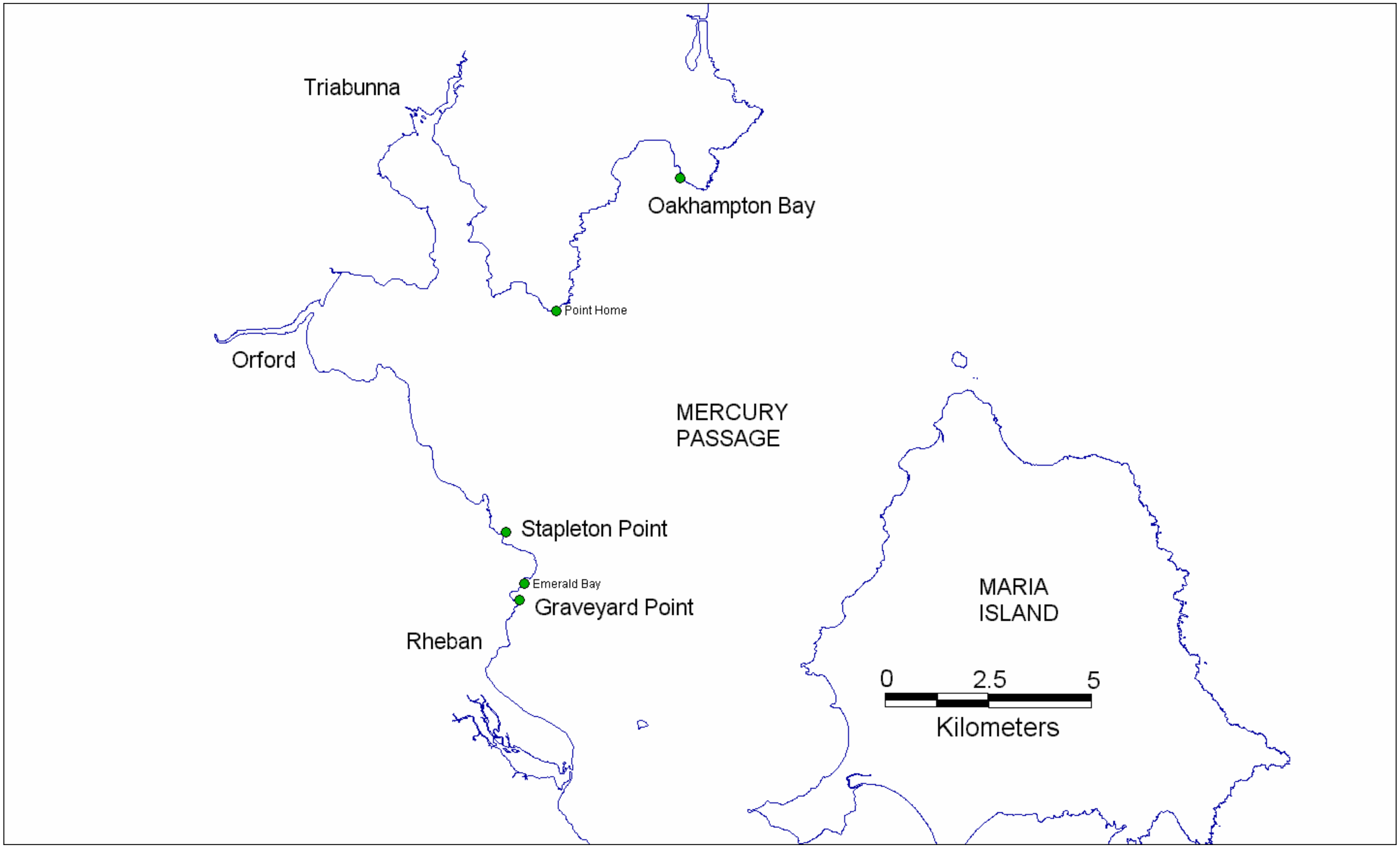


Figure 1.3 Map showing Seacare 'open ocean' sites. Green dots are recipient sites for *Macrocystis* plants. Red stars are donor sites and blue squares are control sites.

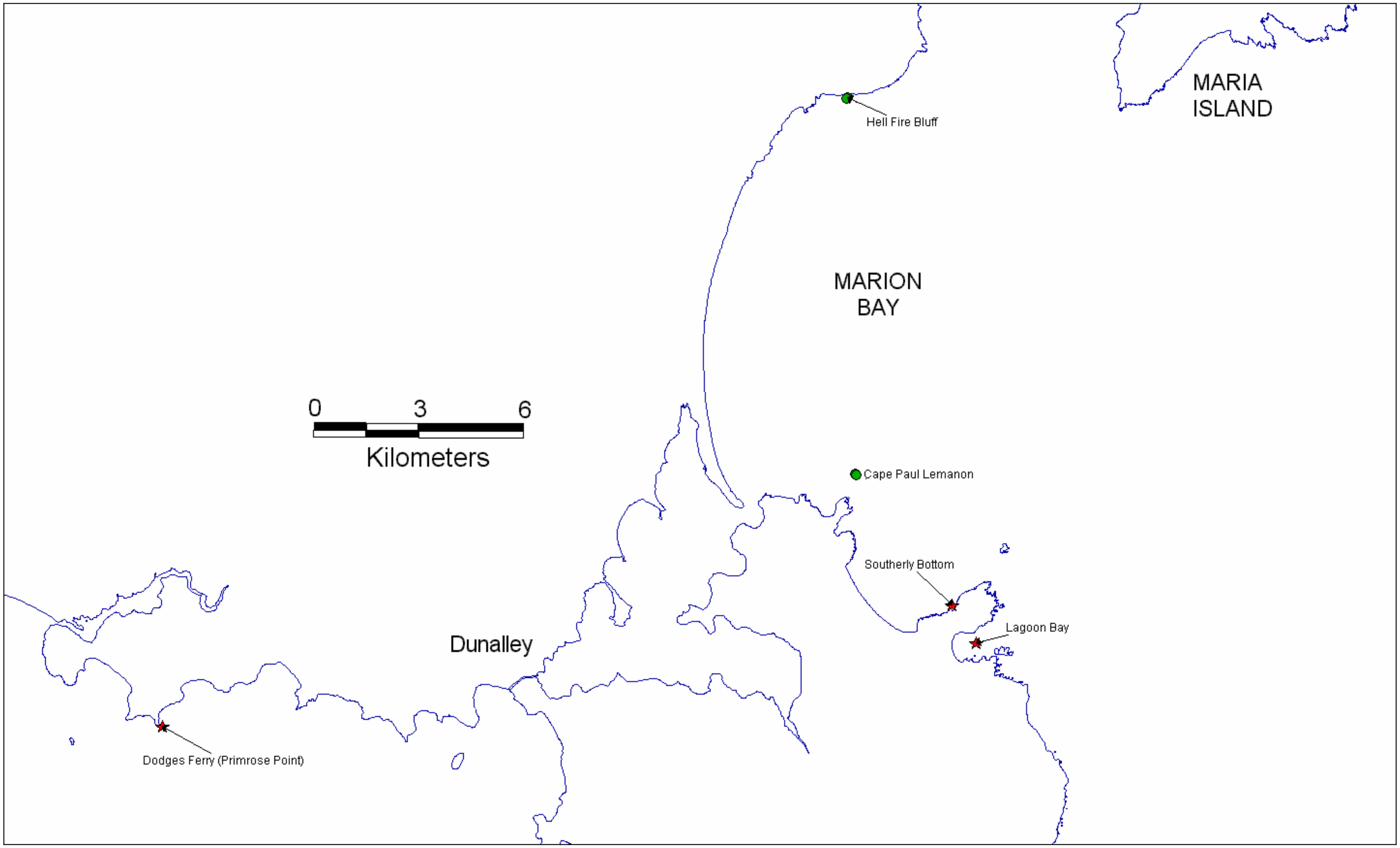
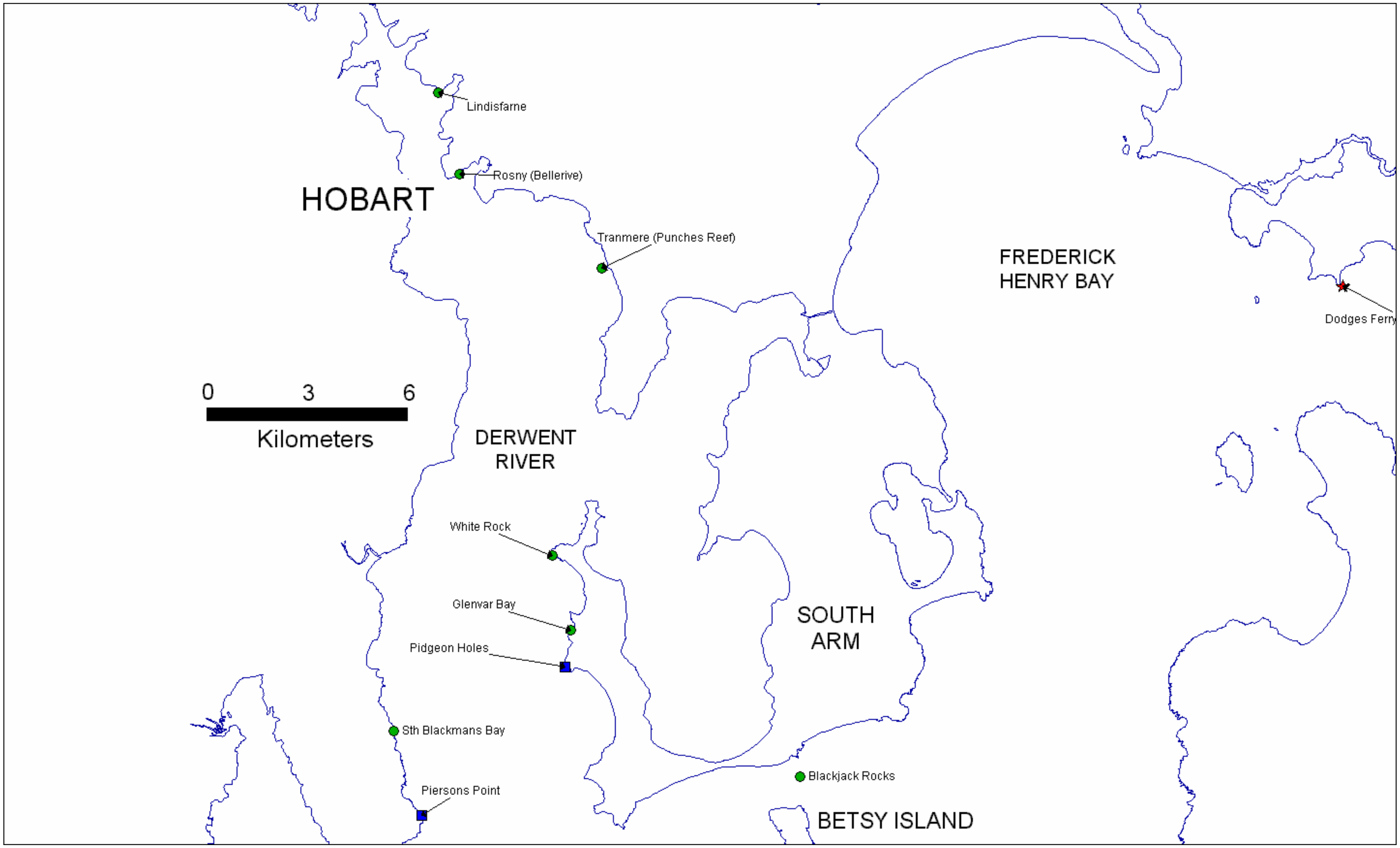


Figure 1.4 Map showing Seacare Derwent Estuary sites. Green dots are recipient sites for *Macrocystis* plants. Red stars are donor sites and blue squares are control sites.



Chapter 2

Macrocystis pyrifera surveys within Tasmania.

Macrocystis beds off the north east Tasmanian coast. Picture taken from a light plane on a *Macrocystis* survey undertaken by Seacare in 1999.

INTRODUCTION

To determine how *Macrocystis* distributions have changed with time in eastern and southern Tasmania, data was sourced from available surveys that have been conducted for *Macrocystis*. The principle sources of information were anecdotal, old maritime charts, and *Macrocystis* stock assessments done in 1950-53 (Cribb 1954), 1965 (Alginates 1965), 1986, 1988, 1999 (Sanderson 1986, 1999). Data was also sourced from DPIWE archives for operating details for a company harvesting *Macrocystis* in the early 1970's (Alginates P/L 1970/01).

Maritime Charts

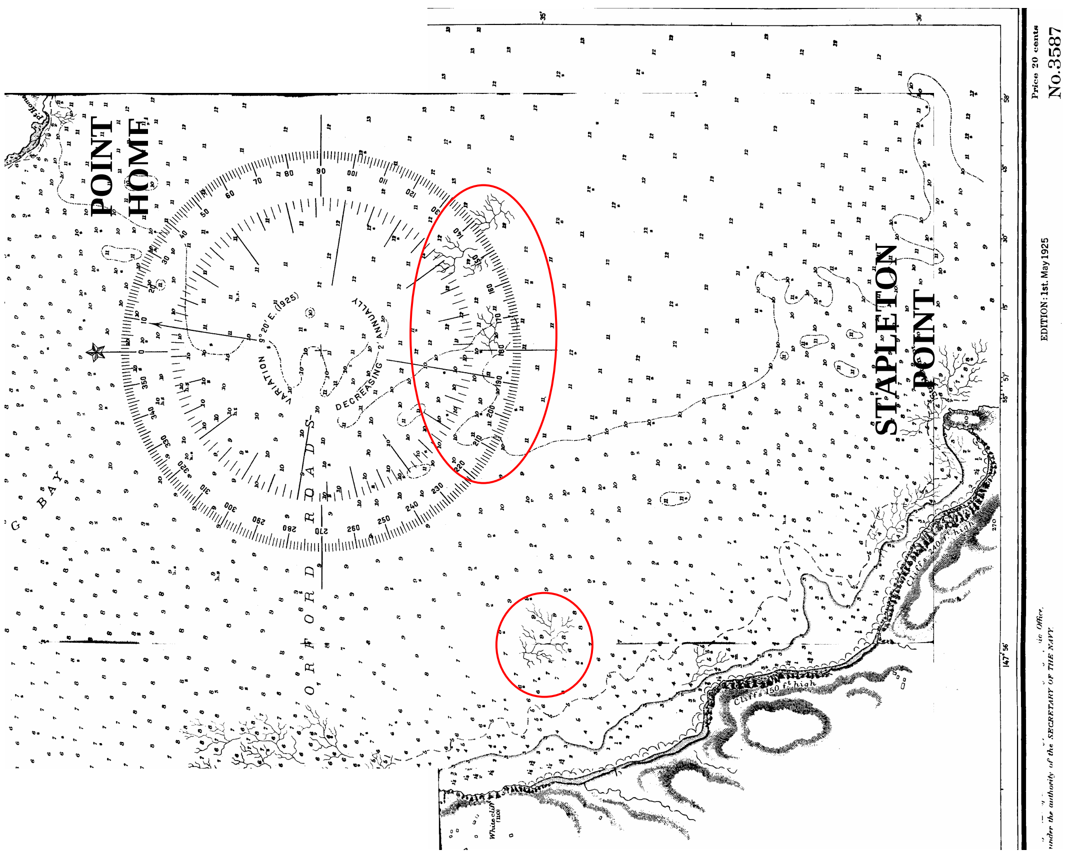
Early maritime charts marked the presence of *Macrocystis pyrifera* as it was a hazard to shipping. The archives in the Tasmanian State library were researched to check for all applicable, available charts. Other sources of data include ships logs. No trace was found of charts by Baudin, an early French explorer who is reputed to have noted large quantities of *Macrocystis* in the Mercury Passage.

Recent maritime charts have kelp beds marked, but it is believed the information is sourced only from previous editions of the maritime charts ie there are no recent surveys of kelp distribution done for maritime charts. The original survey for the maritime charts date back to the late 1880's and there have been few changes on later charts.

Recently, much of the responsibilities for historical data collection in this area have been taken up by a separate NHT project coordinated through the Resource Management & Conservation Division of DPIWE (see www.kelpwatch.tas.gov.au). Seacare did however ground-truth some beds of *Macrocystis* off the coast at the mouth of Spring Bay in the Mercury Passage.

Early and more recent maritime maps consistently show *Macrocystis* beds 1-2 km off Stapleton Point (see figure below). There have been no records of beds existing at these sites over the last 20-30 years and most evidence would suggest the area to be primarily sand substrate which would not support *Macrocystis*. In order to verify the possibility it may have held *Macrocystis* in the past, the area were acoustically sounded and dived on by members of Seacare.

At the more offshore locations (not immediately off Spring Beach) rock substrate was determined, confirming that these sites may have had *Macrocystis* in the early surveys. The rock substrate varied from 10 to 18 m (577528.62, 528145.05; AGD66, AMG Zone 55) depth. The deeper waters consisted primarily of flat platform reef. The shallower areas (577748.71, 5283445.06) of reef of higher relief.



Cribb 1954

Surveys were conducted between 1950 and mid 1953 as part of an assessment of the *Macrocystis pyrifera* beds on the east coast of Tasmania by the Commonwealth Scientific and Industry Research Organization (CSIRO) Division of Fisheries seaweed program in the early 1950's.They were conducted because of interest in the *Macrocystis* beds as a source of alginates. The surveys were not conducted by the author of the paper (AB Cribb) and a description of the methodology for the surveys is not included in the paper. Presumably, the mapping was done from a boat using line of sight.

The survey ostensibly included the entire Tasmanian East Coast, however sections of the Bruny Island and Tasman and Forestier Peninsula's have not been included eg. Fortesque Bay and Lagoon Bay and up around the Gardens areas which might be expected to carry significant *Macrocystis* beds. Fortesque Bay and Lagoon Bay have not known to have been without *Macrocystis* in recent history (last 15-20 years) and likely to have definitely had some at the time of the survey.

Alginates 1965

A research program jointly conducted by Alginates (Australia) P/L and C.S.I.R.O. Division of Fisheries and Oceanography was set up to investigate the relationship between kelp: *Macrocystis pyrifera* and crayfish larvae. Alginates (Australia) P/L, based at Louisville in the Mercury Passage, were harvesting kelp at this time. This study was initiated to address concerns regarding the effect of harvesting on crayfish stocks. The location of the *Macrocystis* beds in this survey are reasonably accurate and agree well with later surveys. There is most inaccuracy in the width of the beds, this is probably +/-20%. Length of the beds along the coasts is probably accurate to within +/-5%. Complete for the Mercury Passage area.

Alginates 1970-71

As a condition of licence for harvesting *Macrocystis pyrifera* (Linnaeus) C. Agardh 1820, Alginates (Australia) P/L lodged harvest returns to the Tasmanian Lands Department (see table). The harvest returns consisted of tonnages harvested location of harvet, when and the length of trip.

While Alginates (Australia) P/L harvested from 1964-1973, harvest data for individual sites is only available for the years 1970-71. In figure "", the data is summed for individual sites for the two years 1970-71. Data presented is taken from Tasmanian Archives and consists of the summed tonnages collected by the harvesting barge of Alginates P/L for the period 1970-71. Data is the total tonnage harvested for all sites within blocks as obtained from the records. Two sites not located (and thus not included) were Bakers Point (151 tons) and Galeena Reef (87tons).

Sanderson 1986

A survey of the east Tasmanian coastline from Musselroe Bay to South East Cape revealed a total of 10 km2 of *Macrocystis pyrifera* kelp forest.

The survey was conducted from a light aeroplane. Areas of *Macrocystis pyrifera* beds were marked on 1:100,000 topographical land tenure maps using landmarks as references. Digitising of bed outlines on maps was done using Mapinfo.

Average harvestable quantities based on Alginates (Australia) Company records (1965-72) show that cropping can expect to yield 5 ton/acre or 1.23 kg/m2. This realizes a total of 12,300 tonne available on the East Coast of Tasmania in 1986. For comparison, weight of *Macrocystis* per unit area is also estimated from quadrats harvested at a number of sites along the coast.

This survey was complete for the east coast of Tasmania in 1986.

Sanderson 1988

In 1984 I initiated studies into the growth, production and biology of a number of the dominant Tasmanain kelps, this included *Macrocystis pyrifera*. Similar to a lot of people I assumed that the distribution of the alga would be fairly stable over time given the size of individual plants and beds.

The survey in 1986 showed a widespread distribution of the alga, with quantities in the same order of magnitude as earlier surveys. I had study sites in Bicheno and south of Southport at George III Reef. Coincident with warm water incursions on the east coast, *Macrocystis* disappeared from large sections of the coast over 1987-1988. At this time, I required field based plants to follow up on growth studies. Anecdotal evidence at the time from fishermen and other marine enthusiasts and personal experience from many field trips, failed to show any significant beds from St Helens to SouthEast Cape.

METHOD

Sanderson, Mount, Ibbott and Baron 1999

In 1999, Seacare conducted a survey for *Macrocystis pyrifera* from Eddystone Point to South East Cape.

The survey was conducted from a light aeroplane. Areas of *Macrocystis pyrifera* beds were marked on 1:100,000 topographical land tenure maps using landmarks as references. A Trimble GPS unit was used to track position in the aeroplane. As boundaries of the beds were flown over, these were marked on the GPS. When plotted up, this information assisted in determining *Macrocystis* bed boundaries where these were not close to the coast.

A Cessna 6 seat aeroplane was chartered from Tasair Pty Ltd leaving from Cambridge airport approx. 10km east of Hobart. The flight was conducted in two stages due to refueling requirements of the aeroplane (approx. 5 hours flying time total).

In the first stage, the area from Marion Bay to Georges Rocks was covered and in the second from Marion Bay to Recherche Bay.

Personal on the flight were the pilot, Craig Sanderson, Mic Baron, Sam Ibbott and Richard Mount.

Responsibilities for these people were respectively:

- Still photographs (Nikon 401 camera with 35-80mm lens, Polarizing filter).
- Video footage (digital camera with provision for taking stills using a frame grabber at a later stage).
- Note taker and marking of boundaries on 1:100000 topographic maps.
- Differential GPS and altitude notes.

At a meeting subsequent to the flight at DPIWE, boundaries of the beds have been translated to 1:25,000 (accurate to 1:100,000) electronic versions of the Tasmanian coast. These have been made available through the Australian Coastal Atlas.

Noted as part of the attributes for the beds when digitising the data. Beds are each given a code ("rel_code","reliab") indicating the reliability of the bed outline. These are:

a	accurate to within 20 metres, all sides of bed well defined
b	some edges of bed well defined but not all
c	estimate of position only, large discrepancies possible
d	no real idea of extent or position
e	doubtful whether bed exists

Macrocystis present on the surface of the ocean is assumed to reflect overall quantities of the alga and distribution. Some areas may have been overlooked where the alga did not reach the surface due to tides or plants in poor condition etc.

There are two species of *Macrocystis* in Tasmania, these are *M. pyrifera* and *M. angustifolia*. These two species generally can be distinguished on the basis of their depth distribution, which can be estimated, from the air. *M. angustifolia* is found in waters with a depth less than 8-10m; *M. pyrifera* is found in waters with a depth > 8-10m. Species determination was noted as part of the attributes for the beds when collecting the data. Beds are each given a code ("spp_code","sp_name") indicating species determination reliability. These are:

a	*Macrocystis pyrifera*
b	*Macrocystis pyrifera?*
c	*Macrocystis angustifolia*
d	*Macrocystis angustifolia*?

Survey comparisons

To compare survey results, the coast was divided up into a number of segments. This was to compensate for inadequacies in individual surveys. Not all previous surveyors surveyed all sections of the coast, and for the areas where the surveys were conducted, not all surveyors surveyed the coasts in similar detail. It is also recognition of the fact the *Macrocystis* beds are very variable in extent. By comparing over large sections of coast, some of this variability is incorporated. On a local scale at the level of kilometres, while one bed is not on one section of coast one year, it may be present for an equivalent area of coast nearby.

It has been noted for most of these surveys that while linear extent of the beds is easy to map, areal extent suffers from much error in determining the width of the beds. The width of the beds is more subject to errors of not seeing fronds as they are below the surface of the water, particularly in deeper waters. Often at the scale of mapping, the width of the beds is comparable to the width of the line used to mark the beds! To companstae for this bed comparisons have been made using the linear extent of the beds.

RESULTS

Macrocystis was easily identified in the water at the height flown (approx. 400’). Most appeared to be *Macrocystis pyrifera* but the *Macrocystis* in the area from Four Mile Creek to St Helens could have been *M. angustifolia* (very shallow).

Large beds* of *Macrocystis* were found from Recherche Bay to Marion Bay and from Binnalong Bay to Georges Rocks. Very little was evidenced on the central Tasmanian coast between Marion Bay and Binnalong Bay except for one large bed off the southern end of Friendly Beaches (see attached map).

Accurate GPS marks and notes on much of the distribution as well as pictorial evidence in the form of still shots and digital video was obtained.

Anecdotal and other evidence suggest that stocks of *Macrocystis* were as high in 1999 in the areas surveyed than at any other time since 1983. Over this period there have been variations from a low of a few hectares (< 5 hectares total at North Bay, Fortesque Bay and George III Reef) in late 1988 to an estimated total now of 2,500 hectares.

In 1999, was not much evidence of the alga between Marion Bay and Schouten Island despite the area having previously been recorded as having quite large beds (Cribb 1954, Button 1968, Sanderson 1987).

The lineal extent of the beds has remained relatively constant over the full extent of the Tasmanian east coast except for the anecdotal survey period between 1987/88. On a local level, in some areas, the amounts of the alga reflect these overall survey results, for example in the vicinity of the Actaeon Islands (see fig 2.2).

Some sections of coast have beds that are very variable from year to year, in particular in the area from Georges Rocks in the north east, south to Schouten Island. Large beds noted in the survey conducted in 1999 off Friendly Beaches and Ansons Bay, for example, were not present a few months later. Their demise is believed to have been coincident with large easterly swells.

In the area in the vicinity of the Mercury Passage, there appears to have been a decline in the quantities of the alga since the first surveys were initiated (see fig 2.3)

Table 2.1 showing relative amounts of *Macrocystis* as determined for sections of the coast across surveys undertaken from 1950 to 1999 as depicted in figs 2.1 - 2.3.

Block Number	Block Length (km)	Total coastline length	Cribb 1954	Alginates 1965	Alginates 1970/71**	Sanderson 1986	Sanderson 1988	Sanderson 1999
1	40	74.7			731	2.2	0.0	29.0
2	40	60.6			0	0.0	0.0	4.2
3	40	60.0			83	2.7	0.0	8.9
4	40	209.9			1102	5.4	0.0	4.3
5	40	186.8	48.6	36.2	2840	7.5	0.4	0.7
6	30	202.2			2138	13.2	0.5	11.2
7	30	245.3	14.9		710	21.9	2.1	18.3
8	40	269.1	12.0		493	10.6	0.5	21.0
9	40	369.8	20.1		1339	46.0	0.3	51.8
TOTAL Blocks 7,8 & 9			**95.6**			**85.9**	**3.2**	**91.8**

DISCUSSION

Overall quantities of *Macrocystis* appear to have changed little on the south and east coasts of Tasmania over the period 1950-1999, for the surveys reviewed. On a local and at a state level, the quantities of the alga can be very variable. Quantities in the northeast of state are most variable with large declines coincident with warm (& low nutrient) water incursions as a result of the east coast current impinging on the Tasmanian coastline, although it is difficult to separate out the impact of large easterly swells. The area in the vicinity of the Mercury Passage appears to be in most decline with the alga having disappeared almost entirely.

Possible Factors Affecting the Alga's Decline

A number of explanations, some involving human interference with the marine environment have been put forward for the disappearance of *M. pyrifera* in the Mercury Passage. These include:

- disturbing the substrate through dredging for scallops in the 1950's. This has resulted in the silting up of inshore reef areas that were formerly colonized by *M. pyrifera* forests. In California, germination of spores of *M. pyrifera* has been shown to be negatively affected by sediment.

- similarly *M. pyrifera* may be affected by the increasing sediment load in coastal waters as a result of land clearing and wood-chipping. Land clearing and wood chipping results in less binding and protection for top soils which are then more susceptible to runoff. These then end up in waterways and are dumped into the sea. This results in more suspended sediment in the water column, cutting light penetration and more sediment on the inshore reefs.

- increase in boat traffic which cuts off growing fronds. This is equivalent to harvesting which has been demonstrated to have minimal effect on healthy *M. pyrifera* beds when conducted in a controlled manner. However, when done on a continual basis and especially with beds that may be unhealthy for some reason will have a deleterious affect.

- the over-fishing of rock lobster which are believed to feed on sea urchins. This has led to an increase in sea urchins which then feed on *M. pyrifera.* In Canada and North America, a relationship has been postulated between crayfish and urchins whereby urchin numbers are controlled by crayfish. The heavy fishing pressure on crayfish has consequently resulted in an increase in the numbers of urchins. This has then bought about an increase in urchin barrens that have resulted from increased numbers of this animal. As in California, divers in Tasmania have observed urchin climbing *M. pyrifera* plants and pulling them down to the substrate where they are eaten. Urchin barrens are the ocean equivalent of deserts on land.

- the commercial harvesting of String Kelp have also been put forward as potential reasons for the declining populations. A company established in the 1960's was established to harvest *M. pyrifera* for alginates. Declining levels of this alga at the time contributed to the collapse of this company in the early seventies. Levels of the alga have since approached former levels, but some areas, a number of which are close to the site of the former alginate factory, have never recovered. Harvesting of *M. pyrifera* to feed juvenile abalone in developing abalone farms is minimal to nonexistent here in Tasmania.

- the recent introduction of *Undaria pinnatifida* (a Japanese seaweed thought to have introduced through ballast waters) which occupies a similar ecological niche to *M. pyrifera* and is thus a potential competitor. In areas where *Undaria* occurs, the alga can form mono-specific stands. The plant can grow up to two meters in length and so effectively 'smother' the reef bottom. This will affect not only *M. pyrifera* but other local plants and animals in an unknown manner.

- there are strong indications that *M. pyrifera* populations have been declining in conjunction with the warming of coastal waters. Maximum annual temperatures and salinities of eastern Tasmania's coastal waters have been rising as measured by CSIRO oceanographers since the 1940's due to more frequent incursions of the warm, nutrient depleted waters of the East Australian Current (EAC) adjacent to Tasmania's coast. In 1987, levels of *M. pyrifera* on Tasmania's east coast were at a minimum (pers obs). This coincided with very warm waters.

- In California, *M. pyrifera* beds have shown to be affected by El Nino. The driving force behind the appearance of the EAC is not known but may be related to El Nino. At present it appears to be affected by the duration and intensity of the westerly winds which drive cooler waters up the east coast of Tasmania. These may tie into a 10 year cycle, the mechanism for which is not yet known. The kelp's poor health is most likely to be caused by the nutrient depleted nature of these waters than the warmth of the water.

Gametophyte resilience

The life cycle of *Macrocystis* includes a heteromorphic alternation of generations. The most visible part of the life cycle is the sporophyte. The sporophyte releases spores, which give rise to filamentous gametophytes that are not readily visible. Gametes from the gametophytes unite to give a sporophyte. The gametophyte is the more resistant part of the life cycle and enables the *Macrocystis* plant to endure periods of physical hardship such as low nutrient warm seawater.

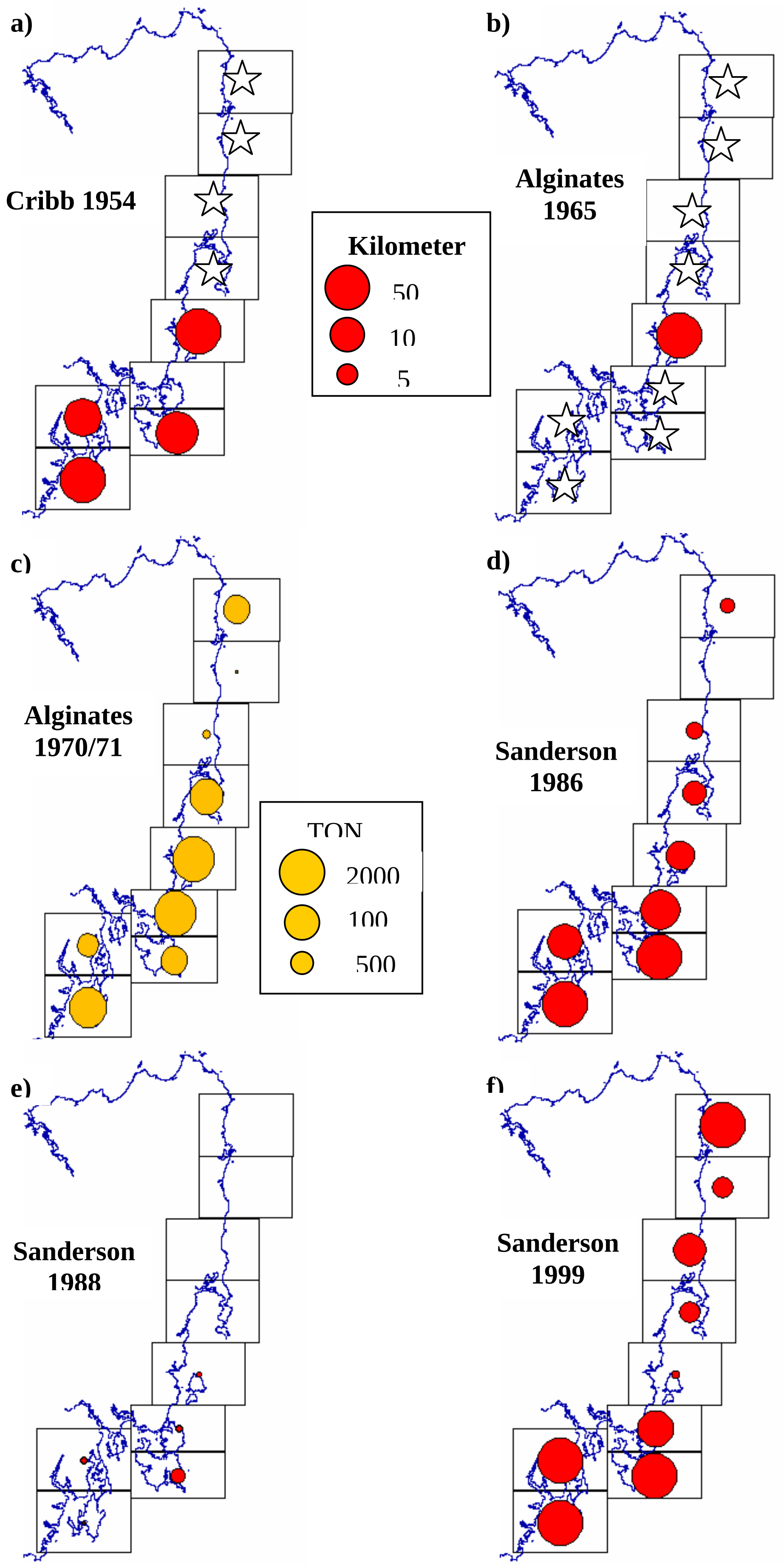
The ready regeneration of *Macrocystis* beds at a number of sites simultaneously in areas where there had been none previously for long periods suggests that the gametophyte stage may be involved in the alga's recovery here in Tasmania. *Macrocystis* may normally be expected to regenerate from drift plants but this is unlikely for the large sections of Tasmania's north east coast where *Macrocystis* beds come and go. This agrees with relatively recent research on the gametophyte stage of *Macrocystis* and other closely related brown alga, which show that some laminarian gametophytes may be able to enter a resting stage and also are resistant to large changes in environmental factors. The gametophyte stage of *Laminaria* spp. For example can exist in darkness for periods of more than 6 months and still live. This has been put forward as a reason why *Undaria* (also closely related to *Macrocystis*) can be transferred from port to port in ballast tanks.

While the indications of these surveys would seem to indicate a relatively overall stable amounts of the alga, it is believed that at present (2003), there are much lower levels of the alga on the Tasmanain coast than detected in the survey of 1999. Easterly swells experienced not long after the 1999 survey wiped out the large beds at Friendey Beaches and Ansons Bay and it is believed there has been little recovery (2003). Are the declines real or can *Macrocystis* weather these declines either in the smaller sporophytic form, not obvious at the surface or as a microscopic gametophyte ready to take advantage of better conditions?

Macrocystis seen on the north east coast of Tasmania agrees with the M. *angustifolia* form of *Macrocystis*. Is the difference between the two species; M. *pyrifera* and M. *angustifolia* real? - could they be environmental morphs? And if not is *Macrocystis pyrifera* disappearing at a rate much greater than currently believed?

- large beds are defined as moderate or greater density extending continuously over an area greater than 0.5 hectares.

FIGURE 2.1 (following page) Length of coastline with *Macrocystis pyrifera* for nine blocks on the east coast of Tasmania, surveys: 1954, 1965, 1986, 1988 and 1999 (blocks not surveyed). Also, tonnage harvested for each of the blocks, 1970/71 by Alginates P/L.


a)
Cribb 1954
Kilometer
50
10
5
b)
Alginates
1965
c)
Alginates
1970/71
TON
2000
100
500
d)
Sanderson
1986
e)
Sanderson
1988
f)
Sanderson
1999

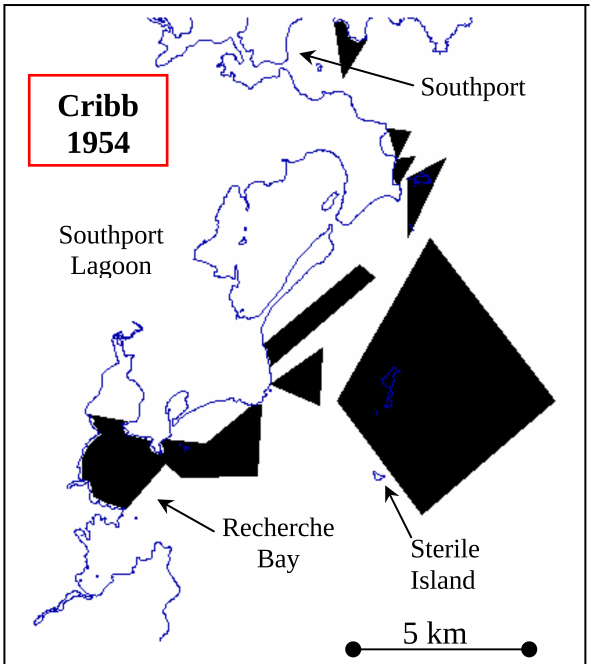


FIGURE 2.2 showing the results of surveys for *Macrocystis pyrifera* for the area between Recherche Bay and Southport. The black areas indicate where *Macrocystis* beds were located at the time of the surveys.

For comparison, the tonnages of *Macrocystis* harvested by Alginates (Australia) P/L 1970/71 are included. Alginates (Australia) P/L havested from 1964 into the early seventies. Harvesting rates quoted by the Company vary up to 8 tonnes per acre with a 5 ton per acre average.

Note for the Recherche Bay - Southport area there has been a good recovery after the loss of the alga late 1988 / early 1989.

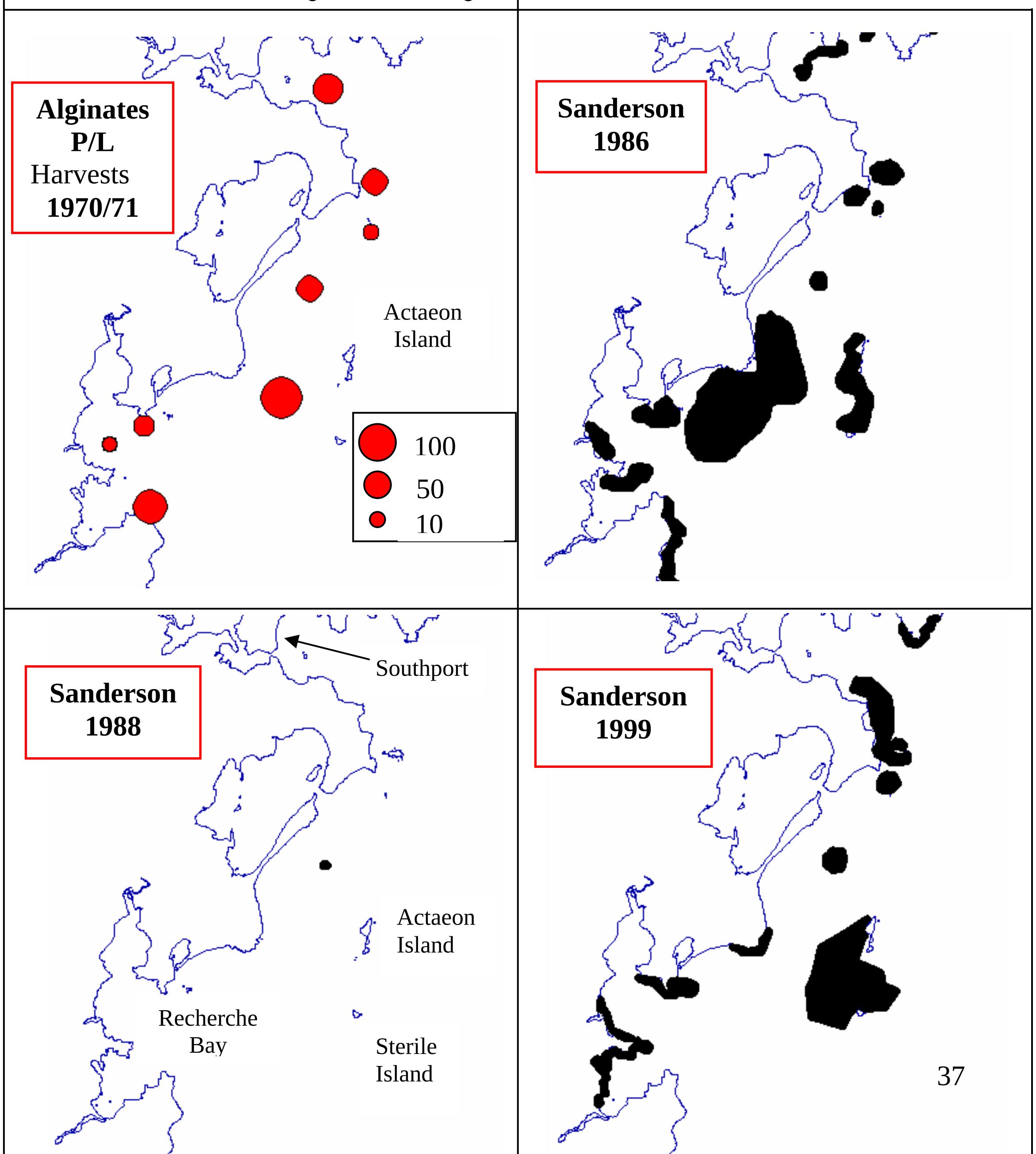
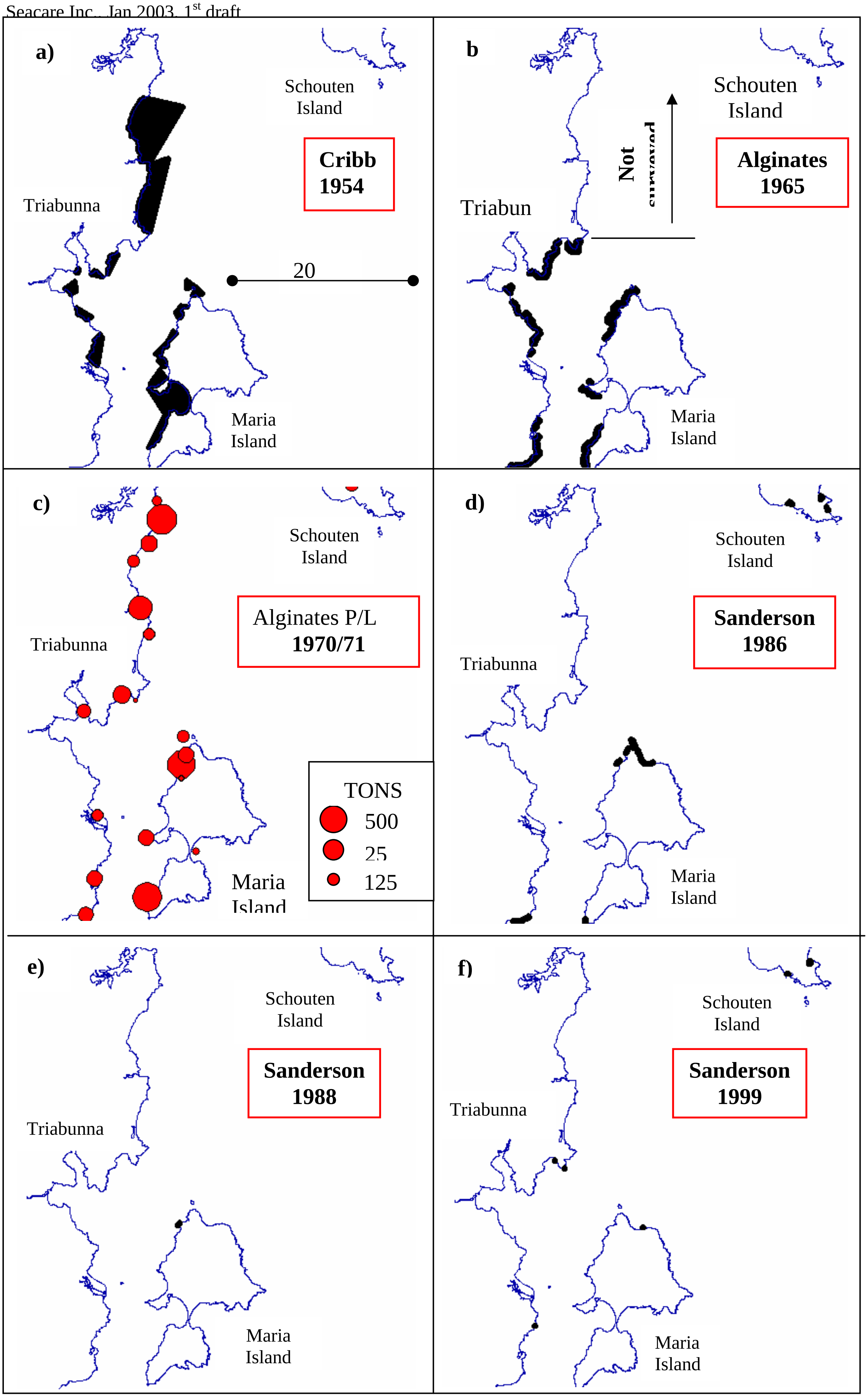


FIGURE 2.3 (following page) showing the results of surveys and tonnage data for Alginates P/L 1970/71 for *Macrocystis pyrifera* in the Mercury Passage north to Little Swanport. Note very little *Macrocystis* present in this area from the late eighties onwards.


a)
Schouten
Island
Cribb
1954
Triabunna
20
Maria
Island
b
Schouten
Island
Not
surveyed
Alginates
1965
Triabun
Maria
Island
c)
Schouten
Island
Alginates P/L
1970/71
Triabunna
TONS
500
25
125
Maria
Island
d)
Schouten
Island
Sanderson
1986
Triabunna
Maria
Island
e)
Schouten
Island
Sanderson
1988
Triabunna
Maria
Island
f)
Schouten
Island
Sanderson
1999
Triabunna
Maria
Island

SURVEY REFERENCES

1/ *Cribb 1954*: Cribb AB 1954 *Macrocystis pyrifera* in Tasmanian waters. Aust. J. Mar. Freshwater Res. 5 1-34. Covered most areas between Recherche Bay and Christmas Island on Tasmania's east coast.

2/ *Alginates P/L 1965:* Olsen AM 1966 (?) Interim report of "An investigation into the effect that the harvesting of *Macrocystis* might have on the stocks of the spiny lobster or marine crayfish, *Jasus lalandei*" by Alginates P/L. Mercury Passage only.

3/ *Alginates 1970/71:* Figures are the total tonnage harvested by location as recorded by Alginates P/L for the years 1970 and 1971 on Tasmania's east coast.

4/ *Sanderson 1986:* Sanderson JC 1987 A Survey of the *Macrocystis pyrifera* (L.) C. Agardh Stocks on the East Coast of Tasmania. Dept. Sea Fish. Tech. Rep. 21, 11 pp. Tasmania's east coast from Eddystone Point to Recherche Bay.

5/ *Sanderson 1988:* Anecdotal distribution of *M. pyrifera* on the east coast of Tasmania at the end of 1988 and early 1989 based on authors experience and other anecdotal evidence.

6/ *Sanderson 1999*. Aerial survey of M. *pyrifera* conducted in August 1999 on Tasmania's east coast from Georges Rocks to Recherche Bay.

Table 2.2 Table showing total tonnages harvested for various sites on the east coast of Tasmania for 1970 and 1971 as noted by Alginates P/L.

Year	Site	Tonnes	Year	Site	Tonnes
1970	Adventure Bay	427	**1971**	Cape Paul Lemenon	619
	Green Point	329		Ansons Bay	469
	Grindstone Bay	245		Bailley Point	416
	Cape Paul Lemenon	241		Lagoon Bay	402
	North Bay	228		North Bay	363
	Cockle Bay	182		Hopgrounds	334
	Okehampton	179		Safety Cove	276
	Long Point (Maria Is)	176		Green Point	204
	Lady Bay	166		Banwell	199
	Sisters Bay	151		Darlington	161
	Hopgrounds	132		Gardens Reef	148
	Trumpeter Bay	130		Grindstone Bay	147
	Bailley Point	122		Paddy's Head	145
	Fortescue Bay	92		Schouten Island	135
	Lagoon Bay	89		Yellow Bluff	130
	Fishers Point	89		Hellfire Bluff	128
	Safety Cove	88		Long Reef	111
	Variety Bay	67		Bakers Point	107
	Southport	64		Black Reef	101
	Southport Island	55		Fortescue Bay	90
	Galeena Reef	47		Boltons Beach	87
	George III Rock	47		Friendly Beaches	83
	Middle Bluff	46		Penguin Rock	77
	Rabbit Island	45		The Gardens	74
	Bakers Point	44		Variety Bay	68
	Port Arthur	44		Trumpeter Bay	68
	Rheban	43		Rabbit Island	66
	Wedge Island	40		Pirates Bay	65
	Sullivans Point	40		Middle Bluff	51
	Hellfire Bluff	31		Cape Frederick	49
	Black Reef	30		Rheban	47
	One Tree Point (Bruny)	25		Okehampton	41
	Blanche Rock	24		Skeleton Bay	40
	Black Reef (Schouton Is)	24		Reidle Bay	40
	Boltons Beach	23		Galeena Reef	40
	Darlington	22		Tasman Head	35
	Long Reef	22		Bull Creek	30
	Lomas Point	20		Adventure Bay	28
	Tower Bay	16		Recherche Bay	20
	Weatherhead Point	12		Major Lord's	16
	Partridge Island	8		Wedge Island	15
	Black Point	7		Tasman Bay	14
				Southport	10

70 Total	3912	George III Rock	8
		One Tree Point (Bruny)	5
		71 Total	**5762**
	Grand Total		**9674**

Chapter 3

Derwent River *Macrocystis pyrifera* reafforestation trials

Figure showing surface fronds of *Macrocystis pyrifera* in the foreground at south Blackmans Bay.

INTRODUCTION

Anecdotal reports suggest *Macrocystis* as having survived in the Derwent Estuary up as far as at least Lindisfarne. One report claimed that:

"the string kelp was so thick at Lindisfarne Point, you had to walk across the top to fish on the outer margin of the bed."

The first of the Seacare *Macrocystis* reafforestation trials was initiated in the Derwent Estuary.

Transplant methodology was based on overseas experience particularly that of Kelco P/L in California (Mc Peak pers com). Kelco P/L run a large *Macrocystis* harvesting program off the Californian coast and they have been involved in a number of kelp re-establishment programs there since the 1970's.

Transplant sites in the Derwent were chosen that had a reef substrate and were exposed to a moderate amount of wave action. Sites were chosen at progressive distances up the river in case there was some factor that moderated downstream such as pollution. Proximity to the open ocean also enhanced the chances of success and was a test of the reafforestion methodology. As *Macrocystis* was already present for the lower south western side of the estuary, and there is little reef present in the north weston which to plant, all transplant sites are on the eastern side of the river.

Initially (1997/98 application) four transplant sites were chosen, these were Tranmere Reef, White Rock, Glenvar Bay and Black Jack Reef. The main donor site was the closest to the transplant sites available with *Macrocystis* at the southern end of Blackman Bay. In order to determine if taking *Macrocystis* juveniles from donor sites had a detrimental affect on the beds at donor sites, a control donor site (Piersons Point) was chosen for monitoring. In case *Macrocystis* bloomed at all sites, and not just at the sites where we were trialling the planting process thus giving a false indication of the success of the program, a control site on the eastern shore (Pidgeon Holes) was also monitored.

In this funding round (application 1997/98), the Binnalong Bay CoastCare group also applied and received funding for growing *Macrocystis* at Binalong Bay. Seacare assisted in formulating a strategy for this group and was involved in initial surveys.

In 1999/2000, Seacare received funding from NHT to conduct further plantings in the upper Derwent at Kangaroo Bluff and Lindisfarne Point, also in the Derwent Estuary.

Methodology

Surveys

Qualified marine biologist led surveys were conducted at the sites prior to transplant. Two surveys were done at each of the sites to account for seasonal variation (summer and winter). At each site a permanent transect line of 4 * 50m transects (a total of 200m) was laid. The transect lines were laid approximately along the 5m ($\pm$ 1m) depth contour line. This was used to conduct surveys for fish, invertebrate and algal communities at each site. Methodology was based on that used for marinepark surveys (Edgar and Barrett 1997).

Fish were surveyed at a scale of 500m^2 per transect giving a total coverage of 2000 m^2 at each site. Only mobile invertebrates were included in the benthic fauna surveys. These were conducted at 50m^2 per transect giving a total coverage of 200 m^2 at each site. Algal cover was measured using a 0.25m^2 quadrat with 50 points. Cover was noted as the number of points intercepted and conducted one for every ten meters of the transects.

Transects were videoed when they were surveyed.

Kelp bed re-establishment methodology

Four methods have been trialled in the Derwent Estuary. These include:

1/ transplanting juvenile plants from healthy donor sites.

2/ Transplanting fertile sporophylls (spore producing part of adult plants) to recipient sites

3/ Culture of spores in the laboratory. This has been achieved by involving the

Marine Discovery Centre at Woodbridge. Students at the Centre have been involved in releasing spores from plants and culturing them up to 0.5 cm long. These are then planted at the sites.

4/ Transferring rope inoculated with *Macrocystis* from beds w3ith *Macrocystis* to areas to other areas. Transect lines have been placed on the reef bottom at a couple of the sites as part of the monitoring program to assist in relocation of the sites. Small *Macrocystis* plants have been found growing on these lines a number of months later. This inspired this forth method of reinitiating *Macrocystis*. Lines can be inocultated within established *Macrocystis* beds and then transferred to areas where there is little *Macrocystis* to reinitiate plants.

More details regarding the above methods can be found in the Seacare handbooks

Volunteers

Talks were given to local SCUBA diving groups indicating the situation with *Macrocystis* in Tasmania and how Seacare was attempting to reinitiate *Macrocystis* beds in areas where they had been historically. A video and a handbook were put together to aid in the educational and recruiting process.

Volunteer divers were used mainly to collect the *Macrocystis* plants from the donor sites, from areas prescribed by the researchers. Volunteers were involved in all aspects of the operation. This included:

Running Seacare meetings
Newsletter writing
Manning information booths at places such Salamanca market and Agfest
Accompanying marine biologists on surveys of sites
Fundraising

RESULTS

Site Descriptions

For the trials, there are seven sites (July 1998) in the Derwent region, and three sites at Binalong Bay (see attached maps). These consist of donor and recipient sites and references sites for each of these. Sites are comparable in depth and substrate.

Survey results for the Derwent Estuary and Binalong Bay sites indicated the most abundant species. In total there were 31 invertebrate species, 30 fish species and 68 algal species recorded.

Donor Site

The site on Northern Lucas point that was chosen as the source for the juvenile *Macrocystis* plants is moderately exposed and supports a healthy coastal community on a dolerite substrate. In total 25 algal species, 16 invertebrate species were recorded here along with 16 fish species.

The most common are as follows;

Common Name	Species name	Svy1	Svy 2	Tot	T/8
Blotch Tailed Trachinops	*Trachinops caudimaculatus*	130	65	195	5
Bullseye	*Pempheris multiradiata*	10	9	19	3
Blue Throat Wrasse	*Notolabrus tetricus*	8	10	18	8
Bastard Trumpeter	*latridopsis forsteri*	9	1	10	4
Jack Mackeral	*Trachuris declivis*	0	300	300	1
Feather Star	*Cenolia trichoptera*	464	341	805	8
Sea Urchin	*Heliocidaris erythrogramma*	176	91	167	8
Sea Cucumber	*Sticopus mollis*	12	15	27	4
Feather Star	*Cenolia tasmainca*	19	0	19	3
Abalone	*Haliotis rubra*	8	7	15	4

Algae

Species name	Surv1	Surv2	Av cover	Count/20
Ecklonia radiata	16	9	12	18
Encrusting corallines	12	4	8	15
Carpoglossum confluens	6	7	7	13
Lessonia caudata	2	3	3	6
Phacelocarpus	1	4	3	8
Callophyllis sp.	1	3	2	10
Rhodymenia sp.	1	2	1	4

Site details

Av Depth (m)	5
Rock	42.5
Sand/silt on rock	0.1
Sand/silt	7.4

Donor Control

This site is adjacent to the donor site but has had no juvenile plants removed. It has similar exposure, substrate, and a very similar community type to the donor site. 11 fish species were sighted here along with 15 invertebrate and 27 algal species. The most common are as follows;

Common Name	Species name	Svy1	Svy 2	Tot	T/8
Blotch Tailed Trachinops	*Trachinops caudimaculatus*	0	112	112	2
Bastard Trumpeter	*Latridopsis forsteri*	44	7	51	5
Blue Throat Wrasse	*Notolabrus tetricus*	10	8	18	8
Leatherjacket	*Meuschenia australis*	1	13	14	3
Bullseye	*Pempheris multiradiata*	0	6	6	2
Feather Star	*Cenolia trichoptera*	985	704	1689	8
Sea Urchin	*Heliocidaris erythrogramma*	197	121	318	8
Feather Star	*Cenolia tasmanica*	48	24	72	6
Velvet Sea Star	*Petricia vernicina*	17	10	27	8
Abalone	*Haliotis rubra*	13	5	18	5

Algae

Species name	Surv1	Surv2	Av cover	Count/20
Encrusting corallines	13	9	11	16
Ecklonia radiata	10	10	10	15
Lessonia caudata	3	6	4	9
Carpoglossum confluens	5	3	4	11
Phacelocarpus	1	7	4	7
Callophyllis sp.	2	5	3	9
Acrocarpia paniculata	3	3	3	8

Site details

Av Depth (m)	4
Rock	47.4
Sand/silt on rock	0
Sand/silt	2.6

Blackjack Reef

Situated in the lee of Betsey Island this site is predominantly a large flat reef with little direct influence of the Derwent River. It is site with the most oceanic influence. This site is a popular spot with fishers. In total 11 fish species were sighted here along with 15 invertebrate and 20 algal species. The most common are as follows;

Common Name	Species name	Svy1	Svy 2	Tot	T/8
Bastard Trumpeter	*Latridopsis forsteri*	20	0	20	1
Blue Throat Wrasse	*Notolabrus tetricus*	13	7	20	7
Cowfish	*Aracana aurita*	11	1	12	5
Purple Wrasse	*Notolabrus fucicola*	7	3	10	6
Leatherjacket	*Meuschenia australis*	0	7	7	2
Sea Star	*Pateriella calcar*	514	217	731	6
Feather Star	*Cenolia trichoptera*	39	59	98	6
Sea Urchin	*Heliocidaris erythrogramma*	49	20	69	8
Ball Urchin	*Holopnustes inflatus*	5	64	69	7
Abalone	*Haliotis rubra*	13	6	19	5

Algae

Species name	Surv1	Surv2	Av cover	Count/20
Carpoglossum confluens	21	26	23	19
Encrusting corallines	20	13	17	20
Reds fine	0	7	3	8
Jeannerettia lobata	2	5	3	5
Perithalia caudata	1	4	2	6
Acrocarpia paniculata	1	0	1	4
Ecklonia radiata	1	0	1	2

Site details

Av Depth (m)	5
Rock	47.6
Sand/silt on rock	0
Sand/silt	2.4

Pidgeon Holes

Situated on south arm, this area was chosen to be the control site for the transplanting as it is central to the other transplant sites. The reef here is complex in structure, changing from rock platform to piles of boulders and rubble. During the surveys we have recorded 13 fish and 15 invertebrate and 27 algal species at this site.

Common Name	Species name	Svy1	Svy 2	Tot	T/8
Blotch Tailed Trachinops	*Trachinops caudimaculatus*	685	35	720	4
Bullseye	*Pempheris multiradiata*	105	0	105	3
Bastard Trumpeter	*latridopsis forsteri*	24	21	45	5
Purple Wrasse	*Notolabrus fucicola*	3	8	11	5
Blue Throat Wrasse	*Notolabrus tetricus*	4	5	9	6
Pygmy Rock Whiting	*Neodax baletus*	8	1	9	4
Sea Urchin	*Heliocidaris erythrogramma*	215	129	344	8
11 Arm Sea Star	*Coscanasterias muricata*	89	41	130	8
Sea Cucumber	*Sticopus mollis*	38	18	56	8
Pencil Slate Urchin	*Goniocidaris tubaria*	25	9	34	7
Crayfish	*Jasus edwardsii*	6	27	33	7

Algae

Species name	Surv1	Surv2	Av cover	Count/20
Ecklonia radiata	6	7	6	10
Fine Reds	0	6	3	5
Zonaria sp.	4	0	2	4
Acrocarpia paniculata	2	3	2	8
Jeannerettia lobata	0	4	2	6
Laurencia	0	3	1	4
Carpoglossum confluens	1	1	1	5

Site details

Av Depth (m)	3
Rock	27.5
Sand/silt on rock	4.2
Sand/silt	18.3

Glenvar Bay

Slightly north of the Recipient control site is situated the first of the recipient sites in the river. This area has similar substrate to Pidgeon Holes but with much less exposure and algal cover. The reef here is covered with a layer of silt. 12 fish and 15 invertebrate and 21 algal species have been recorded including

Common Name	Species name	Svy1	Svy 2	Tot	T/8
Blotch Tailed Trachinops	*Trachinops caudimaculatus*	85	65	15	7
Bullseye	*Pempheris multiradiata*	5	50	55	2
Cowfish	*Aracana aurita*	4	3	7	4
Blue Throat Wrasse	*Notolabrus tetricus*	4	1	5	3
Bastard Trumpeter	*latridopsis forsteri*	3	1	4	2
Globefish	*Diodon nicthemerus*	2	2	4	3
Sea Urchin	*Heliocidaris erythrogramma*	98	230	328	8
11 Arm Sea Star	*Coscanasterias muricata*	154	52	206	8
Sea Star	*Pateriella regularis*	20	22	42	8
Sea Star	*Uniophora granifera*	15	9	24	7
Biscuit Star	*Tosia magnifica*	0	6	6	2

Algae

Species name	Surv1	Surv2	Av cover	Count/20
Brown fine/scunge	27	0	14	10
Reds fine	6	12	9	14
Fine Reds	0	12	6	7
Cystophora retroflexa	1	0	1	2
Reds coarse	0	1	1	4
Rhodymenia sp.	0	1	0	1
Cladostephus sp.	0	0	0	1

Site details

Depth(m)	4
Rock	13.8
Sand/silt on rock	8.1
Sand/silt	28.1

White Rock

The third site for receiving juvenile *Macrocystis* is slightly more exposed than the other sites in the river, but it supports a range of algal species on a complex reef structure. In total 20 fish and 15 invertebrate and 13 algal species have been recorded here. The most common of these are;

Common Name	Species name	Svy1	Svy 2	Tot	T/8
Blotch Tailed Trachinops	*Trachinops caudimaculatus*	175	457	632	5
Bullseye	*Pempheris multiradiata*	180	3	183	4
Prettyfish	*Atherinidae*	0	25	25	1
Blue Throat Wrasse	*Notolabrus tetricus*	4	9	13	5
Banded Stingaree	*Urolophus cruciatus*	4	8	12	7
Sea Urchin	*Heliocidaris erythrogramma*	36	25	61	8
Sea Cucumber	*Sticopus mollis*	26	9	35	4
11 Arm Sea Star	*Coscanasterias muricata*	15	17	32	7
Ball Urchin	*Holopnustes inflatus*	14	1	15	5
Whelk	*Fusinus novaehollandie*	1	10	11	3

Algae

Species name	Surv1	Surv2	Av cover	Count/20
Carpoglossum confluens	13	13	13	15
Ecklonia radiata	5	7	6	11
Encrusting corallines	3	4	3	9
Jeannerettia lobata	1	1	1	4
Zonaria sp.	0	0	0	2
Erythroclonium sp.	0	0	0	1

Site details

Av Depth (m)	4
Rock	26.9
Sand/silt on rock	0
Sand/silt	23.1

Tranmere Reef

The furthest upstream of our initial replanting sites, this area is heavily influenced by fresh water at some times of the year. It has a thin film of silt covering a long low reef that is relatively swell affected in some conditions. 16 fish and 12 invertebrate and 16 algal species have been recorded from Tranmere reef.

Common Name	Species name	Svy1	Svy 2	Tot	T/8	
Blotch Tailed Trachinops	*Trachinops caudimaculatus*	59	715	774	8	
Bastard Trumpeter	*Latridopsis forsteri*	240	131	371	5	
Jackass Morwong	*Nemadactylus macropterus*	20	217	147	3	
Bullseye	*Pempheris multiradiata*	22	23	45	2	
Red Cod	*Pseudophycis bachus*	2	7	9	5	
Sea Star	*Pateriella regularis*		421	497	917	8
11 Arm Sea Star	*Coscanasterias muricata*	43	92	135	8	
Sea Urchin	*Heliocidaris erythrogramma*	103	24	127	8	
Pacific Sea Star	*Asterias amurensis*	7	26	33	5	
Biscuit Star	*Tosia australis*	10	7	17	7	

Algae

Species name	Surv1	Surv2	Av cover	Count/20
Ecklonia radiata	3	2	3	4
Fine Reds	0	3	2	4
Encrusting corallines	1	0	1	3
Codium sp.	0	1	0	3
Ulva sp.	0	0	0	3
Stenogramme sp.	0	0	0	1
Brown Fine	0	0	0	2

Site details

Av Depth (m)	4
Rock	22.9
Sand/silt on rock	4.5
Sand/silt	22.6

Rosny Point

Less than 100m west of the Rosny sewage plant, this site was significant for the large quantities of the green alga *Codium* sp. present at the time of the survey. 6 fish and 7 invertebrate and 4 algal species have been recorded from Rosny Point in our survey.

Common Name	Species name	Svy1	T/4
Blotch Tailed Trachinops	*Trachinops caudimaculatus*	61	4
Banded Stingaree	*Urolophus cruciatus*	6	2
Common Threefin	*Norfolkia clarkei*	3	4
Porcupine fish	*Diodon nicthemerus*	1	1
Pygmy Rock Whiting	*Siphonognathus beddomei*	1	1
Starfish	*Pateriella regularis*	6250	4
Common Seaurchin	*Heliocidaris erythrogramma*	11	3
11 Arm Sea Star	*Coscanasterias muricata*	10	3
Biscuit Star	*Tosia magnifica*	5	3
Japanese starfish	*Asterias amurensis*	4	3

Algae

Species name	Surv1	Count/20
Fine Reds	8	20
Codium	22	19
Reds	1.2	8
Colpomenia	0.2	2

Av Depth (m)	2.5
Rock	9.3
Sand/silt on rock	18.0
Sand/silt	22.7

Lindisfarne Point

The furthest upstream of our replanting sites. It has a thin film of silt covering a long low reef that is relatively unaffected by swell. It is possible that the Tasman Bridge ameliorates swell action on to this part of the coast which would contribute to silt deposition. 10 fish and 2 invertebrate and 1 algal species have been recorded from Lidisfarne Point in our survey.

Common Name	Species name	Svy1	T/4
Blotch Tailed Trachinops	*Trachinops caudimaculatus*	287	4
Banded Stingaree	*Urolophus cruciatus*	7	3
Greenback Flounder	*Rhombosolea tapirna*	5	3
Common Threefin	*Norfolkia clarkei*	3	2
Banded Morwong	*Cheilodactylus spectabilis*	1	1
Sea Star	*Pateriella regularis*	276	4
Japanese Starfish	*Asterias amurensis*	20	4

Algae

Species name	Surv1	Count/20
Fine Reds	9.1	14

Av Depth (m)	1.8
Rock	0
Sand/silt on rock	24
Sand/silt	26

CONCLUSIONS

With distance up the estuary, exposure to wave action and the maximum depth of the reefs decreases, while the amount of sediment and salinity variations increase.

Over 90 species of algae, invertebrates and fish were recorded from the transects. Biodiversity, as measured by the total number of species detected on the transects is greatest in the moderately wave exposed locations, part way up the estuary. There is a sharp drop in number and compliment of species from Tranmere northwards up the river.

Algae
Species indicative of the more wave exposed locations are Cray Weed (*Phyllospora* comosa) and Strap Weed (Lessonia corrugata). In the upper, more sheltered part of the estuary are the green algae: Sea lettuce (*Ulva* spp.) and Dead Mans Fingers (*Codium* spp) and filamentous reds, greens and browns.

Fish
Wrasse and stingarees are very common species in the more wave exposed locations. In the more sheltered locations there are threefins and gobies.

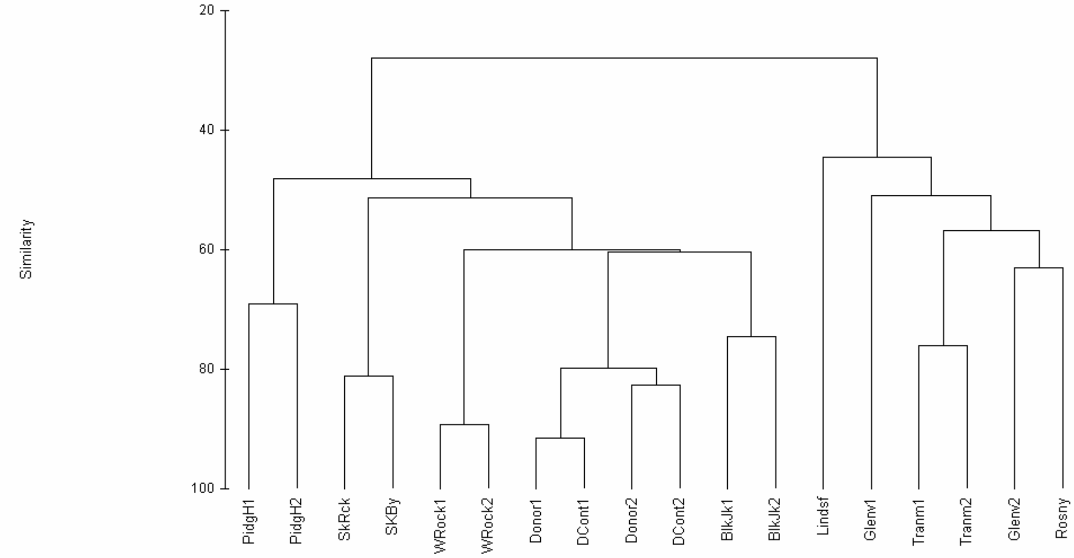
Invertebrates
Species in the more wave exposed locations include crinoids; under rocks and in crevices and the black lipped abalone (*Haliotus rubra*). In the more sheltered locations are the introduced species the Japanese starfish; *Asterius amurensis* and the New Zealand starfish; *Pateriella regularis*.

Reefs in the upper part of the estuary are impacted as evidenced by silt on the reefs, and the presence of introduced species, which are good colonizers of disturbed environments. Algae found in the upper areas of the estuary are indicative of freshwater influence and nutrient enrichment. Reef communities at the mouth of the estuary relatively pristine.

One hundred *Macrocystis* juveniles were planted at Lindisfarne Point, Rosny Point, Tranmere reef, White Rock, Glenvar Bay, Pidgeon Holes and Black Jack Reef with plants from Blackman Bay (Sth) over the years 1998-2000. Plants were also grown at the Marine Studies Center and placed at each of these sites.

The greatest survival and recruitment success was achieved at Black Jack Reef, where there is now a small thriving population. There has also been limited success at White Rock, Tranmere and Glenvar Bay. These sites are all closest to the mouth of the estuary. Exposure to wave action may be assisting their success however factors due to the river such as silt on the reefs, toxicants and salinity variations, which increase with distance up the river cannot be ruled out as adversely affecting populations.

Clustering of sites based on similarities of their species compliment



Ordination of sites based on similarities of their species compliment.

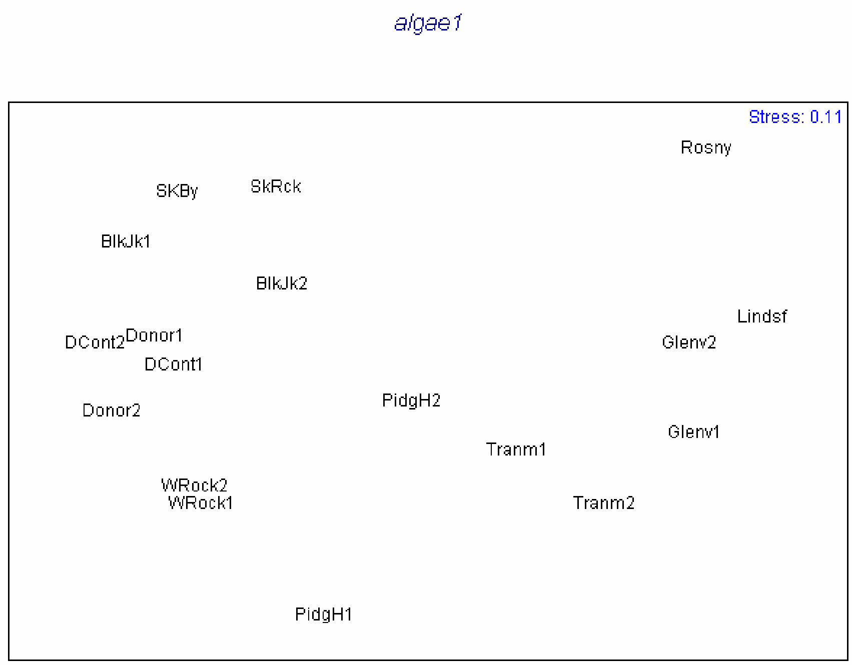


Table showing transplant history for the Derwent Estuary. 'fs' - full survey, 'sp':- cultured plants introduced, text in red is the number of plants transplanted, black is the surviving number.

DATE	DONOR	SITE Blackjack	Glenvar Bay	White Rock	Tranmere Reef	Rosny point	Tryworks Point	Lindisfarne
16-May-98		fs		fs				
17-May-98					fs			
21-May-98			fs					
29-Aug-98	Blackmans Bay	40	25	25				
30-Aug-98	Blackmans Bay				106			
26-Sep-98	Blackmans Bay		**60?**	**60?**				
13-Dec-98			fs					
20-Dec-98		fs						
5-Mar-99				fs	fs			
24-Apr-99		**9**	**15**	**2**	**4**			
5-Jun-99	Blackmans Bay	50						
27-Jun-99	Blackmans Bay		50	50				
1-Dec-99		**18** + juv	**4**	**5**	**12**			
12-Apr-00								fs
15-Apr-00						fs		
16-Jul-00		**10**	**0**	**2**	**0**			
17-Sep-00	Blackmans Bay					50		50
8-Oct-00	Blackmans Bay						50	
1-Nov-00				50		50		50
17-Nov-00	MSC:- sp		sp	sp	sp	sp,+		sp,+
13-Aug-01		sp	sp	sp	sp	sp		sp
16-Mar-02		**10**	**0**	**2**	**0**	**0**		**0**
Totals juv transplants		90	75	125	106	100	50	100
Totals adult sporophylls		**3**	**3**	**3**	**3**	**3**	**3**	**3**
Culture innoculations		**1**	**2**	**2**	**2**	**2**	**0**	**2**

Coordinates for sites mentioned in the text. See apropriate figure in the introductory chapter for a map showing relative site locations (AGD66, AMG Zone 55).

Site	Lattitude	Longitude	Purpose
Skeleton Rock	611,133.92	5,432,624.95	Recipient
Skeleton Bay	611,053.13	5,432,374.21	Recipient
Blackjack Rocks	539,274.81	5,234,869.13	Recipient
Pidgeon Holes	532,238.19	5,238,148.55	Control
Glenvar Bay	532,415.44	5,239,244.51	Recipient
Piersons Point	527,963.90	5,233,702.69	Control
Sth Blackmans Bay	527,134.35	5,236,237.00	Donor
White Rock	531,868.94	5,241,472.86	Recipient
Tranmere (Punches Reef)	533,328.93	5,250,027.72	Recipient
Rosny (Bellerive)	529,087.82	5,252,824.69	Recipient
Lindisfarne	528,466.55	5,255,249.81	Recipient

Chapter 4

Mercury Passage *Macrocystis pyrifera* reafforestation trials

INTRODUCTION

Aim of program: To see if the introduced seaweed, *Undaria pinnatifida* is preventing re-establishment of String Kelp (*Macrocystis pyrifera*) in the Mercury Passage.

Undaria pinnatifida is an annual kelp, thought to have been introduced in ballast waters of woodchip boats that dock at Triabunna. The alga forms dense mono-specific stands that blanket large areas of reef bottom. It occupies a similar niche to the local giant string kelp (*Macrocystis pyrifera*). Large stands of this alga can be seen in the Mercury Passage area from August to late January. From Janaury to March the alga disappears, and nothing is visible from March to May. In June the alga starts growing again.

METHODOLOGY

Four areas were chosen for the work in the Mercury Passage. These are at Oakhampton Bay, Stapleton Point, Emerald Bay and Rheban (Graveyard Point). Five sites have been marked with concrete filled tyres with sub surface bouys in each of these areas at approximately 5m depth. These sites are in urchin barren areas that anecdotally had *Macrocystis* beds twenty or more years ago but now support healthy stands of *Undaria*.

The treatments areas were for 5m around each tyre. This area, while it appears small – can most efficiently be searched by volunteer groups and should be sufficient to serve as a later recruitment source for *Macrocystis* plants to the area.

The project has been designed to show whether it is urchins, *Undaria* or a combination of both that may be keeping *Macrocystis* out should we be successful in reinitiating *Macrocystis*.

Treatment 1:
Undaria removed, *Macrocystis* added
Treatment 2
Urchins removed, *Macrocystis* added
Treatment 3
Undaria and urchins removed, *Macrocystis* added

Treatment 4
Control, *Macrocystis* added
Treatment 5
Control

Surveys

To monitor for changes associated with the manipulations surveys were conducted by qualified biologists. The biologists surveyed for fish, invertbrates and seaweed.

Surveys are conducted at each of the sites quarterly for the first year and then annually (November - December) from then on.

Macrocystis reinitiation

A number of means of introducing *Macrocystis* was trialled. These included

1/ Juvenile transplants (as per the Seacare Handbook)

2/ Mature sporophylls were transported from donor sites and tied off to the tyres at each of the sites

3/ *Macrocystis* was grown on a number of different substrates including rope, gravel etc (see Seacare *Macrocystis* Culture Handbook) and placed over the sites.

Donor Sites

Plants were collected from a number of different areas. These were

1/ Southerly Bottom and Lagoon Bay. These areas have healthy beds of Macrocystuis and are relatively close to the Mercury Passage.

2/ Friendly Beaches. As this site is north of Mercury Passage, the plants may be more temperature tolerant - thus more suitable for translocation than plants south of Mercury Passage.

3/ Primrose Sands (Dodges Ferry). Plants have been used from this site before with good success at Dover and Stapleton Point (early 1990s).

Video

Broadcast quality videos have been taken at each of the sites at regular intervals to monitor the effect of the treatments. The videographer videoed at 1m above each of the tyres in an anticlockwise direction. Stills have been taken from the videos for reporting purposes.

Site maintenance

As *Undaria* is an annual alga and the urchins are mobile, the sites needed to be continually cleared of *Undaria* and urchins. This was done by volunteers and the Seacare biologists. As most movement of urchins occurred in autumn and early winter and the *Undaria* began growing for the new season at this time, there was more regular clearing during this period.

RESULTS

For the first planting season, 2000/2001, survival of *Macrocystis* was very poor. Sites that did not have urchins cleared had the highest mortalities irrespective or where the plants came from (Southerly Bottom or Friendley Beaches).This was also a very warm year and this factor seems to have impacted on plant survival.

In the second season 2001/2002, plants were introduced initially from Southerly Bottom. Again there was high mortality in sites with urchins. Obviously we were wasting our time introducing *Macrocystis* if the urchins were not cleared out so for the transplant from Dodges Ferry later that year, plants were introduced only into urchin cleared sites. We had the best success with these transplants.

Recruitment

No recruitment has been evident at any of the sites in the Mercury Passage despite the varying methods of introducing *Macrocystis* to each of the sites.

Graphs at the end of the chapter (figs 4.1 - 4.6) summarise the biologists findings with respect to the biota at the sites under the various treatments. Pictures in figs 4.7 to 4.11 show graphically the effect of the different treatments. The urchin cleared areas have prolific growth of native algae. These areas subsequently have greater numbers of invertebrates such as abalone and *Comanthus* sp. (feather stars)

DISCUSSION

Plants from Primrose Sands appear to give the best chance of success for the transplant operations. Primrose Sands is a relatively sheltered environment in Frederick Henry Bay. The plants come from quite shallow waters and seem to be more mature than plants of the same size obtained from Southerly Bottom. It is this maturity that might contribute to the enhanced chances of success using plants from this site.

Stunted

Most of the plants that survive from the transplant operation are stunted. This has happened at nearly all sites and occasions. Is this a reflection of the low nutrient conditions at the sites? Only once, have plants grown to full height, this has been at Emerald Bay. Plants were placed here at the same time as plants at the other sites - so why did they only grow larger here. Perhaps there may have been greater nutrient availability for a critical part of the transplant operation. Perhaps this nutrient depletion or water type triggers the M *angustifolia* form of the plant?

Undaria pinnatifida

As there has been very limited success in reestablishing the *Macrocystis*, it is not possible as a result of this program to determine if *Undaria* may be inhibiting return of *Macrocystis*.

At present nutrient availability and urchins determine *Macrocystis* success in the Mercury Passage.

Urchins

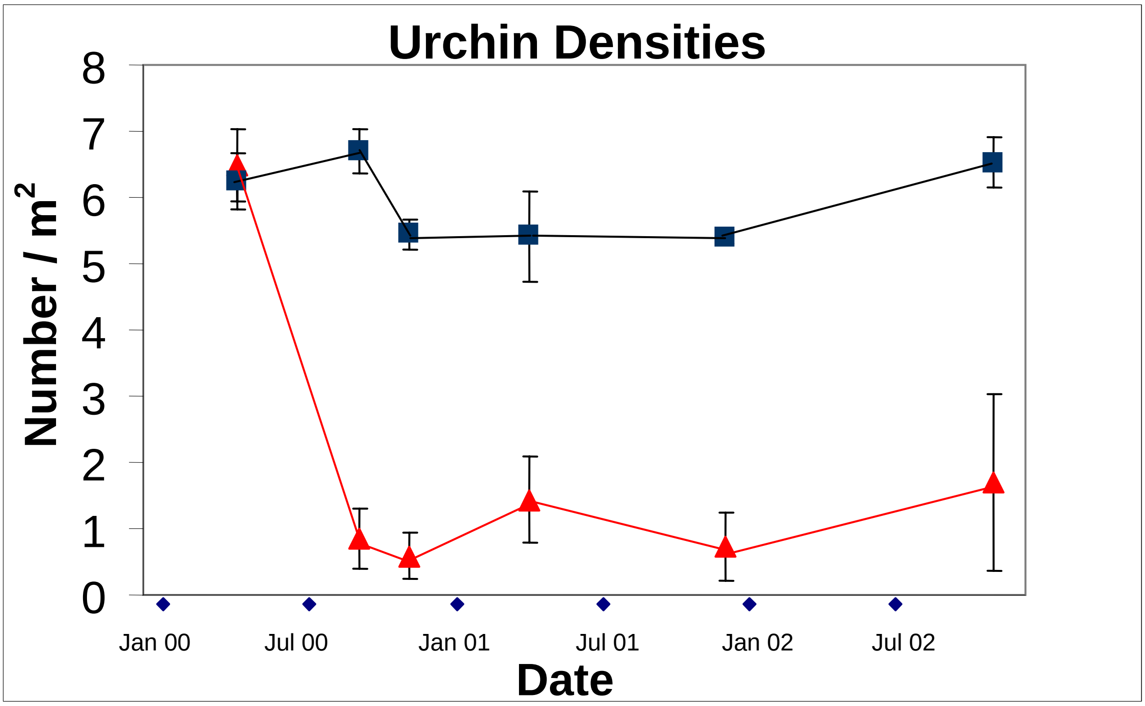
Clearing of urchins appears to increase biodiversity and is better for inverebrates such as abalone and feather stars (*Comanthus* spp.).

Table showing transplant history for the Mercury Passage Oakhampton Bay and Stapleton Point. 'fs' - full survey, 'sp':- cultured plants introduced, text in red is the number of plants transplanted, black is the surviving number.

DATE	**DONOR**	**Oakhampton Bay**						**Stapleton point**					
	Tyre number		**5**	**1**	**3**	**4**	**2**		**1**	**4**	**5**	**3**	**2**
			Cont	***Mac***	***Und***	***UndUrch***	***Urch***		***Cont***	***Mac***	***Und***	***UndUrch***	***Urch***
1-2/04/2000		FS						FS					
27-28/05/2000		prep						prep					
30-Jun-00	Southerly Bottom	20 (*4)		20	20	20	20						
1-Jul-00	Southerly Bottom							20 (*4)		20	20	20	20
8-9/07/2000		prep?						prep					
9-10/09/2000	Southerly Bottom, MSC	10 (*4), FS, sp		10	10	10	10	10 (*4), FS, sp		10	10	10	10
15-Oct-00	Friendly Beaches							10 (*4)		10	10	10	10
18-Oct-00	Friendly Beaches	10 (*4)		10	10	10	10						
18-19/11/2000	MSC:- sp	FS, sp						FS, sp					
1-Apr-01		FS, 0	0	0	0	0	0	FS,1	0	0	0	0	1
20-May-01	Southerly Bottom	10 (*4)		10	10	10	10	10 (*4)		10	10	10	10
16/06/2001			0	6	4	7	8		0	0	0	7	1
16-Jun-01						+	+					+	+
5-Aug-01	Dodges Ferry	20 (*2), sp				20	20	20 (*2), sp				20	20
21-Dec-01		FS, 30	0	1	1	15	13	FS,13	0	0	0	8	5
4-Apr-02		9	0	0	0	8	1	6	0	0	0	3	3
25-May-02		2	0	0	0	2	0	3	0	0	0	2	1
18-Jul-02	MSC:- sp												
24-Oct-02		2						4					
26-Nov-02		FS, 1	0	0	0	1	0	FS, 4	0	0	0	3	1
	Totals juv transplants	**240**						**240**					
	Totals adult sporophylls	**12**						**12**					
	Culture innoculations	**2**						**2**					

Table showing transplant history for the Mercury Passage Emerald Bay and Graveyard Point sites. 'fs' - full survey, 'sp':- cultured plants introduced, text in red is the number of plants transplanted, black is the surviving number.

DATE	**DONOR**	**Emerald Bay**						**Graveyard Point**					
	Tyre number		**5**	**2**	**3**	**4**	**1**		**2**	**1**	**4**	**3**	**5**
			Cont	***Mac***	***Und***	***UndUrch***	***Urch***		***Cont***	***Mac***	***Und***	***UndUrch***	***Urch***
1-2/04/2000		FS						FS					
27-28/05/2000		prep						prep					
1-Jul-00	Southerly Bottom	20 (*4)		20	20	20	20	20 (*4)		20	20	20	20
8-9/07/2000		prep?						prep					
9-10/09/2000	Southerly Bottom, MSC	10 (*4), FS, sp		10	10	10	10	10 (*4), FS, sp		10	10	10	10
15-Oct-00	Friendly Beaches	10 (*4)		10	10	10	10	10 (*4)		10	10	10	10
18-19/11/2000	MSC:- sp	FS, sp						FS, sp					
1-Apr-01		FS,2	0	0	0	1	1	FS,4	0	0	0	2	2
20-May-01	Southerly Bottom	10 (*4)		10	10	10	10	10 (*4)		10	10	10	10
16/06/2001			5?	0	2	8?	6		0	0	0	8	5?
5-Aug-01	Dodges Ferry	20 (*2), sp				20	20	20 (*2), sp				20	20
21-Dec-01		FS,19	0	0	0	8	11	FS, 20	0	0	0	12	8
4-Apr-02		12	0	0	0	4	8	12	0	0	0	8	4
25-May-02		9	0	0	0	2	7	7	0	0	0	6	1
18-Jul-02	MSC:- sp												
24-Oct-02		2						4					
26-Nov-02		FS, 2, sp	0	0	0	1	1	FS, 4	0	0	0	3	1
Totals juv transplants		**240**						**240**					
Totals adult sporophylls		**12**						**12**					
Culture innoculations		**3**						**2**					


Urchin Densities
Number / m^2
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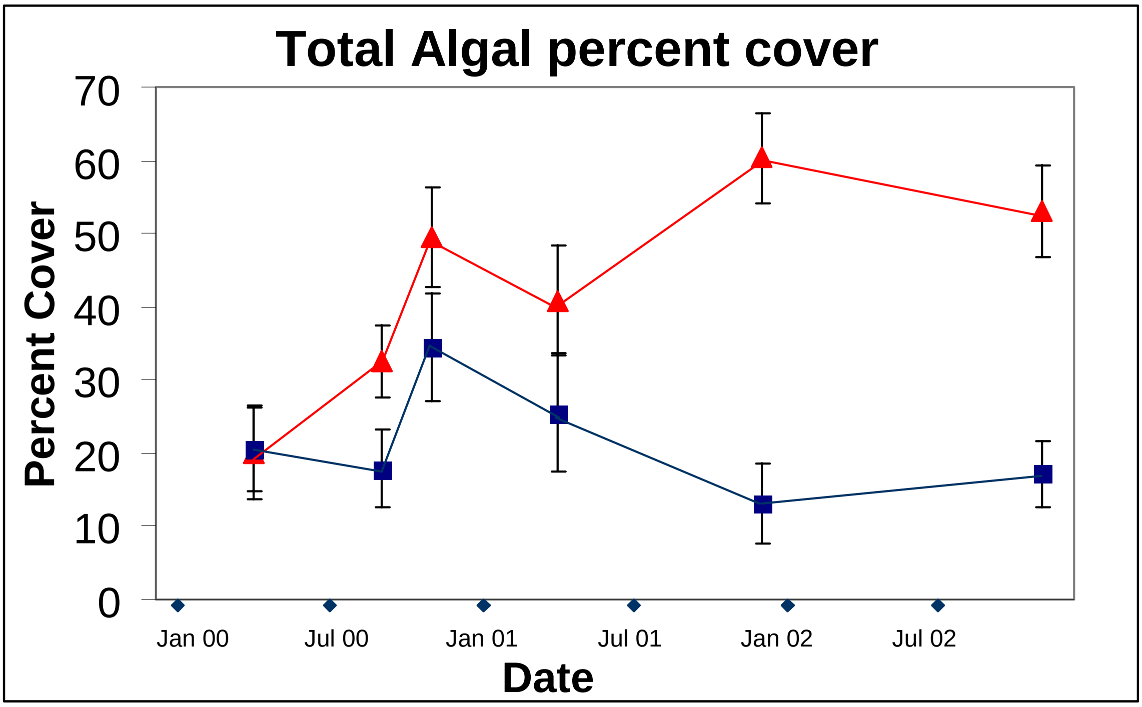
1
2
3
4
5
6
7
8
Jan 00
Jul 00
Jan 01
Jul 01
Jan 02
Jul 02
Date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Percent Cover
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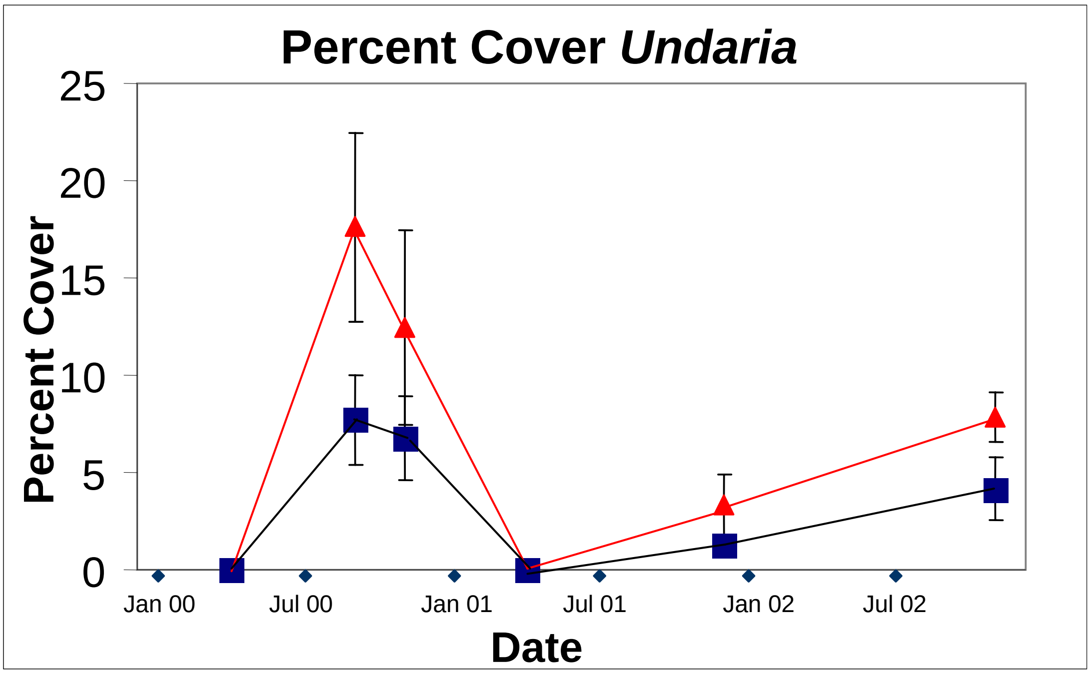
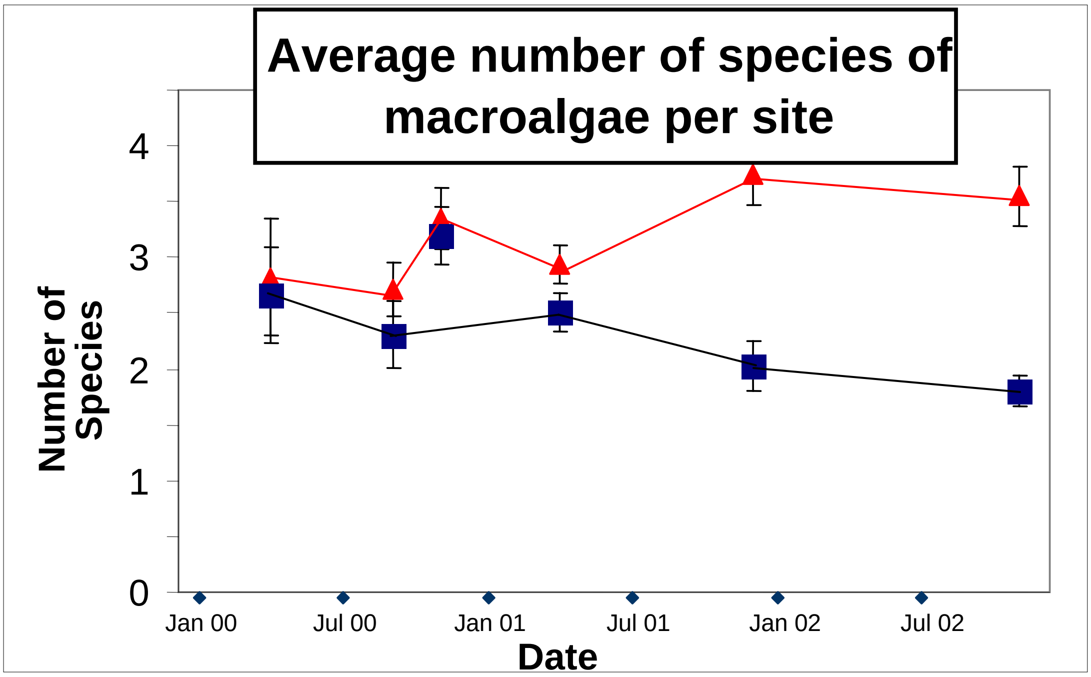
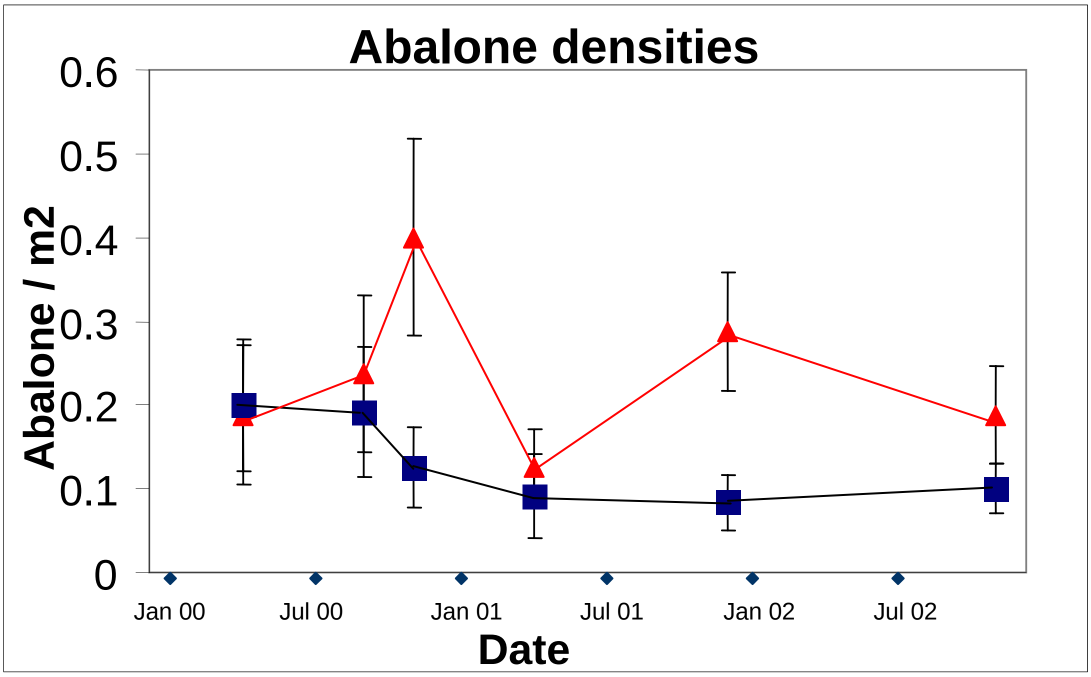
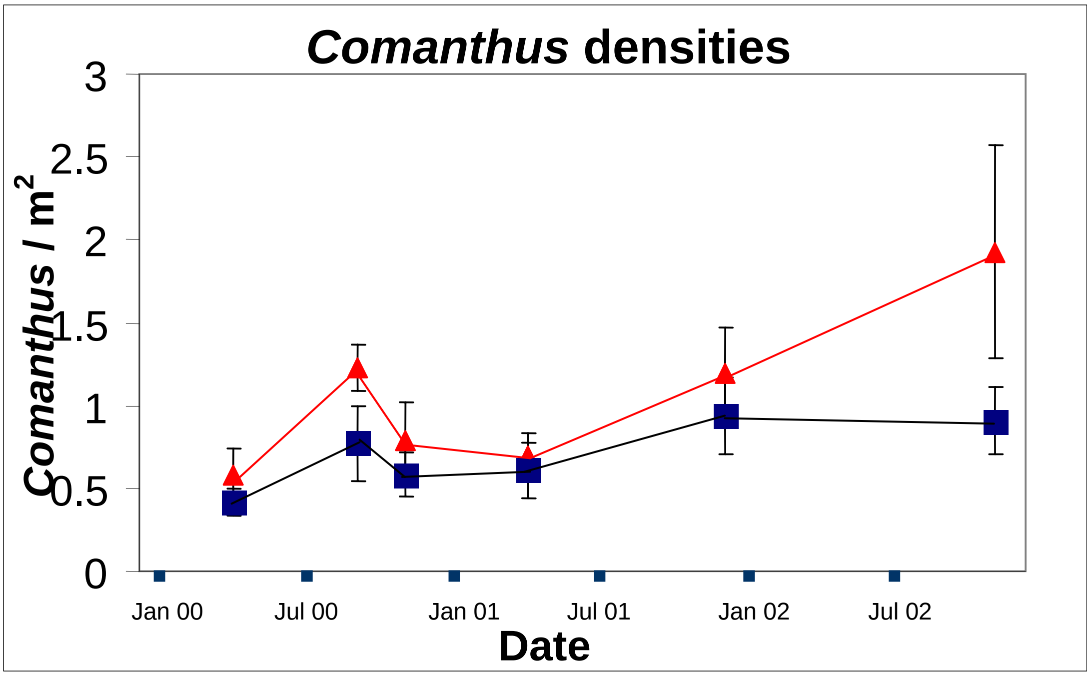
10
20
30
40
50
60
70
Jan 00
Jul 00
Jan 01
Jul 01
Jan 02
Jul 02
Date


Percent Cover *Undaria*
25
20
15
10
5
0
Percent Cover
Jan 00
Jul 00
Jan 01
Jul 01
Jan 02
Jul 02
Date


Average number of species of macroalgae per site
4
3
2
1
0
Number of Species
Jan 00
Jul 00
Jan 01
Jul 01
Jan 02
Jul 02
Date


Abalone densities
Abalone / m2
0.6
0.5
0.4
0.3
0.2
0.1
0
Jan 00
Jul 00
Jan 01
Jul 01
Jan 02
Jul 02
Date


Comanthus densities
Comanthus / m2
3
2.5
2
1.5
1
0.5
0
Jan 00
Jul 00
Jan 01
Jul 01
Jan 02
Jul 02
Date

Coordinates for sites mentioned in the text. See appropriate figure in the introductory chapter for a map (AGD66, AMG Zone 55).

Site	Lattitude	Longitude	Purpose
Friendley Beaches	605,380.62	5,368,886.07	Donor
Oakhampton	580,968.98	5,291,386.75	Recipient
Stapleton Point	576,754.37	5,282,848.89	Recipient
Emerald Bay	577,202.25	5,281,596.43	Recipient
Graveyard Point	577,089.43	5,281,203.55	Recipient
Southerly Bottom	578,078.98	5,252,966.21	Donor
Lagoon Bay	578,794.88	5,251,878.25	Donor
Dodges Ferry (Primrose Point)	555,510.00	5,249,510.45	Donor

Figs 4.7 - 4.11 (following pages) are time series pictures at a selection of sites in the Mercury Passage to demonstrate typical changes in biota under the various treatments. Note also seasonal changes with much more seaweeds present in the November 2000 (spring) picture.

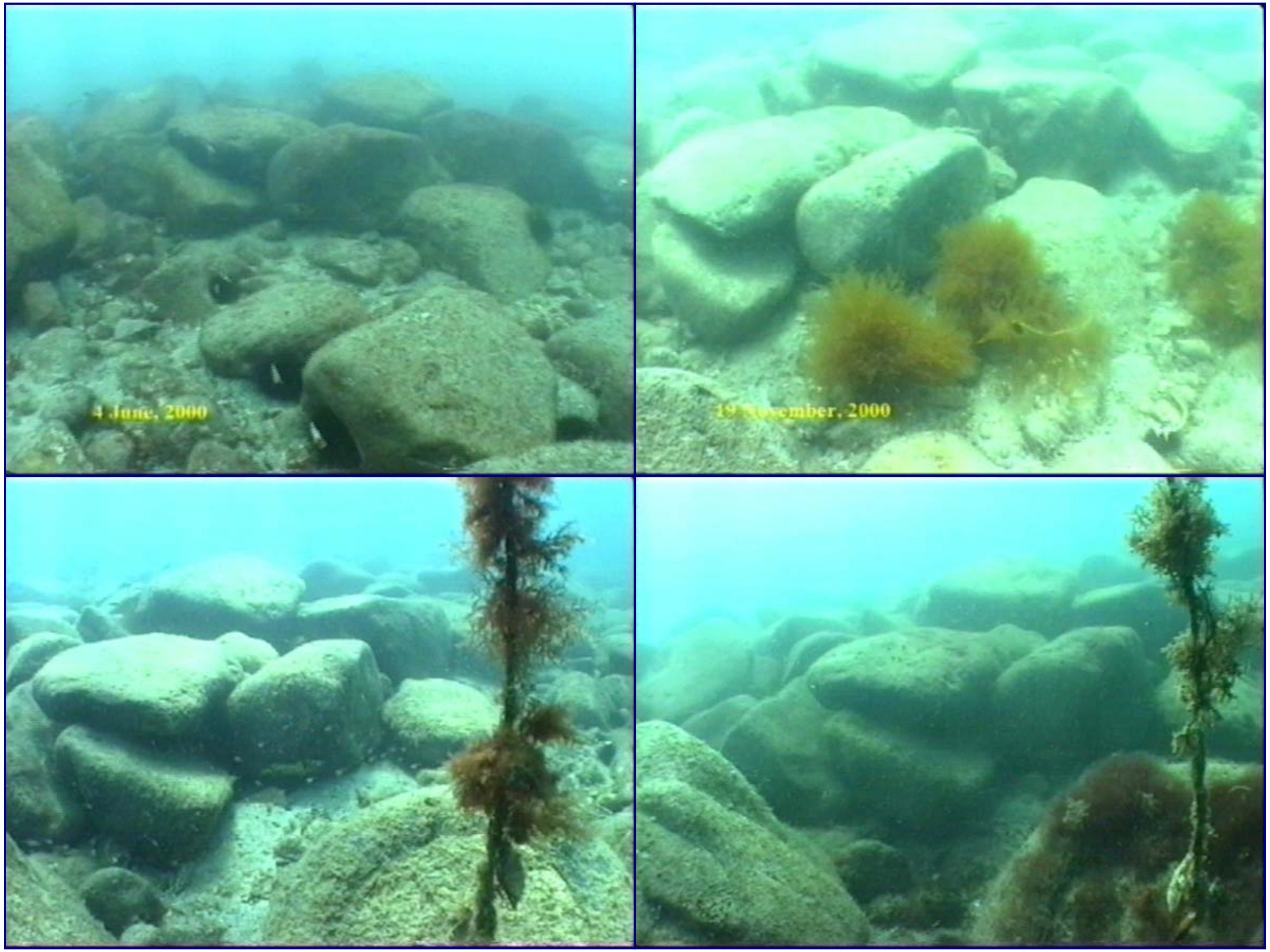
Fig 4.7 Emerald Bay No *Undaria*.(NOUND) Upper left: 4 Jun 2000, upper right: 19 Nov 2000, lower left: 25 Feb 2001, lower right: 4 April 2002.

Fig 4.8 Graveyard Point No urchin or *Undaria* (NOURCHUND). . Upper left: 4 Jun 2000, upper right: 19 Nov 2000, lower left: 25 Feb 2001, lower right: 4 April 2002.

Fig 4.9 Graveyard Point *Macrocystis.*(MAC) . Upper left: 4 Jun 2000, upper right: 19 Nov 2000, lower left: 25 Feb 2001, lower right: 4 April 2002.

Fig 4.10 Oakhampton - No urchin. (NOURCH) . Upper left: 4 Jun 2000, upper right: 19 Nov 2000, lower left: 25 Feb 2001, lower right: 4 April 2002.

Fig 4.11 Emerald Bay No *Macrocystis.(*NOMAC) . Upper left: 4 Jun 2000, upper right: 19 Nov 2000, lower left: 25 Feb 2001, lower right: 4 April 2002.



Chapter 5

Open Coastal *Macrocystis pyrifera* reafforestation trials

Picture showing multiple *Macrocystis* recruits on household brick, Cape Paul Lemenon, Nov 2002.

Picture showing multiple *Macrocystis* recruits on site marker concrete filled tyre, Cape Paul Lemenon, Nov 2002.

INTRODUCTION

All Seacare *Macrocystis* transplant trials in the Mercury Passage have been done in urchin barren areas without a lot of success. Some plants have survived, but only in areas where urchins have been cleared. Ongoing success at these sites is dependent on urchins being continually cleared. Also, many of the surviving plants in the Mercury Passage have been pale suggesting nutrient deficiency. To increase our chances of success, new sites were selected again in areas where there has been *Macrocystis* historically but in more wave exposed waters where there are fewer urchins and there is likely to be greater nutrient availability.

Sites were selected on the east coast in the vicinity of the Mercury Passage. Three sites were chosen: Point Home, Hell Fire Bluff and Cape Paul Lemenon. Cape Paul Lemenon in particular was the area noted by Alginates (Australia) P/L as being where 10% of all *Macrocystis* they harvested in 1970/71. There was no *Macrocystis* prior to these transplants and there has been none there as long as members of Seacare are aware (since the early 1980's).

METHOD

Each site (deep and shallow) was marked with a concrete tyre with a subsurface buoy. These buoys were relocated using GPS. Around each site, plants of other species were cleared, these were principally the kelps *Ecklonia radiata* and *Phyllospora* comosa. At the Cape Paul Lemenon site in particular, growth of these two algae was prolific. It is believed this may be a factor in limiting reestablishment of *Macrocystis*.

To test for differences with depth of recipient sites, planting was trialled at 6m and 11m. Deeper water is believed to be cooler and more nutrient enriched. Sites were marked with GPS to aid in relocation. Surface buoys were not used due to the risk interference by fishermen and others.

Previous experience leads us to believe the origin of the transplants may be play a factor in transplant success. For this project plants were obtained from Southerly Bottom and some from Primrose Sands. Plants from Primrose Sands have proven to be more successful previously.

At the time of transplanting, so that plants from each of the sites may be distinguished, two different colour bricks were used. Initially, twenty from each donor site were planted at the two depths at each site.

The transplants from Primrose Sands proved to be the most successful and subsequently were used solely for future transplants.

At each site, when transplanting, mature sporophylls from the donor sites were also attached to the base of the tyres and sporelings grown on gravel and other substrates at the Marine Discovery Centre were dispersed around the concrete tyre markers. A number of different methods of initiating the *Macrocystis* was used to maximise the chances of success.

Picture showing new recruits at Cape Paul Lemenon on the reef surface. Note small size of plants with frond division resulting in stunting.

RESULTS

As this project was initiated in the previous year (2002), results are still only preliminary however already they are proving to be more promising than all previous Seacare transplants.

The most success had been at the Cape Paul Lemanon site (see table 5.1 below) where there has been good success of transplants as well as very strong recruitment of new plants (see figs).

Preliminary results show that plants from Dodges Ferry are more successful for use in transplants.

Transplants into deeper waters are also proving to be more successful.

CONCLUSIONS

Transplant Origins

While results are preliminary, better survival of plants has been achieved with those from Primrose Sands. As mentioned previously, this is believed to been due to the plants from this site being more mature for the size of the plant. Primrose sands is relatively shelteredfrom wave action and as a consequence, *Macrocystis* grows quite shallow. Plants of comparable sizes from Southerly Bottom have fewer fronds. A mark of the maturity of the Primrose Sands plants is that they sometimes sporophylls.

Deeper Water

Preliminary results here suggest that there is greater survival for the deeper transplants. This may be due to two factors. The first is the lower swell action experienced at depth. This lessens the likelihood of plants being taken at times of high swells. The second is better nutrients at depth.

Surviving plants at both sites appeared stunted (see fig). This has occurred consistently across many transplants in different areas but not all. This may be due to the time of planting. If nutrients are low, this may result in stunting of growth . No mention of this occurring elsewhere has been found in the literature.

Picture taken at Hellfire Bluff showing transplant from Primrose Sands with *M. angustifolia* features ie flattened holdfast producing haptera mainly from its sides, Nov 2002.

Picture taken at Cape Paul Lemenon showing stunted transplant within cleared area , Nov 2002.

Picture taken at Cape Paul Lemenon at the edge of the cleared area to show thickness of surrounding kelp forest and the rate at which new growth was advancing the cleared area, Nov 2002.

Table 5.1 showing transplant history for the 'Open Ocean' sites. 'fs' - full survey,'sp':- cultured plants introduced, text in red is the number of plants transplanted, black is the surviving number.

DATE	DONOR	Point Home			HellFire Bluff		Cape Paul Lemanon	
			SHALLOW	DEEP	SHALLOW	DEEP	SHALLOW	DEEP
10-Sep-00	Southerly Bottom, MSC	40?						
20-May-01	Southerly Bottom	40						
3-Jul-02			PREP	PREP	PREP	PREP	PREP	PREP
18-Jul-02	MSC:- sp		PREP, sp	PREP, sp	PREP, sp	PREP, sp	PREP, sp	PREP, sp
28-Jul-02					40	40	40	40
29-Jul-02	Primrose & Southerly Bottom		40	40				
17-Oct-02		??	?	2	2	2	0	5
17-Oct-02	Primrose Sands		20	20	20	20	20	20
26-Nov-02		??	5	15	5	6, rr	6, rr	17, rr
Totals juv transplants			**200**		**120**		**120**	
Totals adult sporophylls			**4**		**4**		**4**	
Culture innoculations			**1**		**1**		**0**	
							Grand Total	**440**

Coordinates for sites mentioned in the text. See appropriate figure in the introductory chapter for a map of the area (AGD66, AMG Zone 55).

Site	Lattitude	Longitude	Purpose
Point Home, shallow	577,970.93	5,288,181.06	Recipient
Point Home, deep	577,987.80	5,288,169.77	Recipient
Hell Fire Bluff, shallow	575,097.54	5,267,442.58	Recipient
Hell Fire Bluff, deep	575,082.41	5,267,405.99	Recipient
Cape Paul Lemenon, shallow	575,313.23	5,256,691.67	Recipient
Cape Paul Lemenon, deep	575,352.11	5,256,674.69	Recipient
Southerly Bottom	578,078.98	5,252,966.21	Donor
Lagoon Bay	578,794.88	5,251,878.25	Donor
Dodges Ferry (Primrose Point)	555,510.00	5,249,510.45	Donor

Chapter 6

Volunteers

Volunteers dispersing plants at Emerald Bay in the Mercury Passage.

The program for re-establishment of *Macrocystis* at all sites was labour intensive and the working environment difficult.

Factors wotrking against the use of volunteers working in and on the sea include:

1/ time limited: most amateur divers are limited to one SCUBA tank dive/day. Thus at the depths we were operating, this is usually less than 1.5 hours.

2/ cold: often inadequate protection from the cold and sometimes adequate protection allowed limited time underwater. Even the surface, working in the boat, cold temperatures also limited contributions of volunteers and tested enthusiasm.

3/ although 'volunteering' most amateur divers sought recompense by spending part of their time underwater foraging either for abalone or crayfish - further limiting their contribution

4/ after spending one or two times many volunteer divers had 'been there and done that' and went off and did other things

5/ the vagaries of the weather made it difficult to predict dive dates especially for the last part of the project which was articularly exposed to wind and swell. This also made it difficult to maintain volunteer enthusiasm.

6/ Working in water has its own set of difficulties. Amateur divers often have difficulty working in the medium which takes time to overcome even before they can concentrate on the task at hand

6/ Because of the above difficulties, training of divers was problematic as there was minimal continuity and when in the water there was little time.

There was an emphasis by Seacare on the achievement of objectives stated for the project and these turned out to be fairly ambitious. This necessitated only using volunteers in tasks that involved minimal skill levels. There was not enough time allocated within the project to train volunteers in tasks that required moderate skill levels.

Another major problem was the issue of insurance for the volunteers involved. Seacare operated under the belief that if the volunteers were involved with SCUBA diving clubs while diving for Seacare, then they would be covered under the banner of national insurance (NAUI). This however was never confirmed.

Only a few volunteers were maintained for the duration of the project. Many came once or twice for the experience and then dropped out. This complicated the training process for the transplanting. Achievement of objectives relied heavily on the hands on approach of the roject supervisor and assitant.

Future projects should require

- a full time project officer
- insurance cover for volunteers
- larger operating budget

Future projects

At the Mercury Passage sites, regular video at set locations was conducted. This was graphic evidence of the effect of manipulating environmental conditions such as removal of urchins. The sites were within urchin barren areas and are likely to have been caused as a result of overfishing of rock lobster.

Much interest has been expressed by the Tasmanian Amateur Fishing Association in 'adopting' an area of coast between Rheban and Johnsons Point in the Mercury Passage with the intent of closing the reef area to all fishing and then conducting fishdowns of urchins from the barrens which constitute the majority of the reef area between these two sites.

The area could be monitored by biologists and changes to biota determined. Changes should include recovery of macroalgae, and more invertebrates such as rock lobster and abalone returning. Fish species and number should also increase. If the area was closed to fishing, the reefs may attain some sort of balance akin to their original state fifty or more years ago. This would be good evidence for the value of marine reserves in preserving Tasmanian flora and flauna.

Appendix 1

Macrocystis Reforestation Handbook

SEACARE

MACROCYSTIS TRANSPLANT HANDBOOK

Inside a String Kelp forest, shafts of light penetrate the blades to reveal a tremendous variety of marine life. Beautiful red seaweeds which prefer diffused light, grow in the cover of the kelp canopy. Fish and schooling invertebrates such as mysids shelter from predators. Crayfish, sea urchins, abalone and herbivores graze on attached and drift laminae. Small fish, eels, crabs, isopods, worms, sponges and others shelter in the strong anchoring holdfasts. Bryzoans and sessile organisms grow on the surface of the plants which are in turn preyed upon by organisms such as fish and nudibranchs. Lobsters feed on the sea urchins. The long fronds of the alga also trap larvae of fish species, abalone and crayfish ensuring these species recolonize close to the coast.

Charles Darwin wrote in 'The voyage of the Beagle' (1860) after observing *M. pyrifera* forests off Tierra del Fuego:

> ...The number of living creatures of all orders, whose existence intimately depends on the kelp, is wonderful.....I can only compare these great aquatic forests of the southern hemisphere, with the terrestrial in the intertropical regions. Yet if in any country a forest was destroyed, I do not believe nearly so many species of animals would perish as would here, from the destruction of the kelp.

Unfortunately the opportunity to dive in Tasmania's String Kelp forests is becoming increasingly rare. String Kelp forests are disappearing from our coastal waters. Surveys carried out by CSIRO, the Tasmanian Department of Primary Industry and other institutions have documented the decline of *M. pyrifera* to the present. Anecdotal evidence based on observational skills and knowledge of fishers back up these surveys.

Binnalong Bay, St Helens, Bicheno, Maria Island, Fortesque Bay and Eaglehawk Neck are all situated on Tasmania's east coast and have all been amongst the many places where string kelp forests have thrived.

Commonly, areas formerly occupied by *M. pyrifera* now are inhabited primarily by forests of less spectacular, less productive, much smaller brown algae such as *Ecklonia radiata* and *Phyllospora comosa* or are bare urchin infested rocky substrate or they might be barren, sediment covered reefs.

This handbook has put together specifically to assist two groups: Seacare; in the Hobart region and the second: the Binalong Bay Coastcare group at Binalong Bay. Both groups are interested in re-initiating *Macrocystis* in areas where it has formally been abundant but is no longer present. Both groups are concerned for implications this loss of habitat might have on dependent animal life including lobster, abalone and fin fish species.

PLANT DESCRIPTION, BIOLOGY AND DISTRIBUTION

Macrocystis is a brown alga of which four species recognized, these are; *M. integrifolia*, *M. angustifolia*, *M. pyrifera* and and *M. laevis* . *Macrocystis* spp. are found in cold temperate oceans with surface temperatures ranging from 0 to 20ºC, and their main distribution is circumpolar in the southern hemisphere, between 40 and 60º S longitude They are also present in the major upwelling areas including the west coast of South Africa, the Pacific coast of South America and in North America from Baja California north.

Two species of *Macrocystis* exist in Australian waters, these are *M. pyrifera* and *M. angustifolia*. *M. pyrifera* appears to be confined to south east Tasmania, occurring mainly in depths of 8-22m. *M. angustifolia* is distributed from Cape Jaffa, South Australia to Walkerville, Victoria including the north and NW coasts of Tasmania. *M angustifolia* occurs principally in coastal waters of 0-10m depth. Intergrades of the two species are believed to occur down as far south as the D'Entrecasteaux Channel.

Macrocystis pyrifera is the largest of the kelps and forms dense beds adjacent to the coast. Plants of *Macrocystis pyrifera* may be 4-20 m high. Each plant consists of many fronds which attach to rocky substrate at the base by a conical holdfast bearing branched root-like haptera. The fronds bear blades in the upper portions. The fronds grow from the tip progressively spliting off new blades. A mature blade is 30-150 cm long and 5-15 cm broad and is attached to the stipe via a vesicle, 4-12 cm long. The vesicles act as floats, keeping the fronds orientated vertically in the water column; the upper portions remain at or near the surface, where they often form a dense canopy.

Frond ages have been measured from 7 to 12 months old in Tasmania. This compares with estimated ages of 5-8 months in California, 12-13 months in the Falkland Islands. Plants may exist for many years regularly shooting up fronds.

The plants produces spores formed in specialized blades, usually without vesicles near their bases, called sporophylls. The spores arising from the sporophylls give rise to filamentous gametophytes which then give rise to gametes. Male and female gametes fuse giving rise to the zygote and thence the large plant or sporophyte with which we are familiar. This type of life cycle is termed a heteromorphic alternation of generations.

HISTORY IN TASMANIA

In the 1950's, interest was directed at the Tasmanian *Macrocystis* beds as a possible alginate resource. In 1954, a study conducted through the Commonwealth Scientific and Industry Research Organisation (CSIRO) estimated a standing crop of approximately 118,000 wet tons at one harvest per year, with a total area of approximately 120 km^2. A company was initiated in the 1960's to harvest this alga. A survey conducted prior to this company starting to harvest indicated a possible annual tonnage of 11,000 wet tons.

Whilst operating, the company realized in most areas a single harvest per year rather than three as anticipated and the maximum amount of the alga that was harvested in any one year was 9000 tons. In the late sixties and early seventies, the amounts of the alga declined, coinciding with increasing mean annual sea-water temperatures and in 1972 the company ceased harvesting as the enterprise was no longer financially viable.

In 1986 another survey was conducted for a separate company applying to harvest the alga. Estimates of the standing crop were again in the vicinity of 10-12,000 wet tons forming a total area of approximately 8 km^2. Permission to harvest was not granted by the local Department of Fisheries.

In 1987 the quantities of *Macrocystis pyrifera* decreased dramatically, again coinciding with increasing annual mean sea-water temperatures. In 1988, the total amount of *M.pyrifera* evident on the Tasmanian coastline was reduced to less than an estimated 0.5 km^2 (pers. obs.). Since then levels of the alga have slowly increased to approximately a quarter of levels surveyed in 1986 (1996).

There is some doubt as to the authenticity of the original estimates of quantities of *M. pyrifera* made by Cribb, especially as one of the larger beds recorded by Cribb is within what is presently a large sandy bottomed bay and appears to always have been so (Chinamans Bay, Maria Island). Other areas do however have little or none where there appears to have been large quantities in the past (The Gardens, Oakhampton Bay, Stapleton Point).

Table 3. Findings of major seaweed surveys of the stocks of *Macrocystis pyrifera* on Tasmania's East coast.

Surveyor	Weed Area -Acres	Tons/ Acre	Weed Available	Cuts/ year	Yearly Harvest
Cribb (1954)	30,000	5	120,000	3	360,000
Button (1961)	1,993	4	11,143	3	33,429
Alginates 1965/72	3,000	approx. 5		1+	6,500-14,000
Sanderson/ Light(1986)	2,530	5	12,650	1 1/3	16,870

Table 4. Change in estimated quantities of *Macrocystis* based on survey reports at some select sites.

Area	Cribb 1954	Button 1961	Alginates 1965	Alginates 1965/72	Sanderson/ Light 1986
Grindstone Bay	8,240	140	80	525	nil
Southern Maria Is	4,064	150	20	55	10
Actaeon-Southport	58,116	310	not given	not given	1,970

GROWTH AND PRODUCTIVITY

A study on the growth of *Macrocystis pyrifera* conducted between 1985 and 1989 at two sites in Tasmania demonstrated a mean length increment of approximately 5 cm/day over a period of two years, with a maximum of 11 cm/day recorded for an individual frond over 75 days (see figs below).

Mean blade production was 0.5 blades per day with a maximum of 1.7 blades per day over 45 days. Annual productivity of *M. pyrifera* at the two sites suggests similar productivities of 24 kg/m^2 wet weight. This was 4-6 times the estimated productivity of local species also monitored in the areas.

FIGURE Graph showing measured growth rates of *Macrocystis* plants measured as increase in the number of blades at two sites on Tasmania's coast. Each point is the average measurement of 15 fronds.

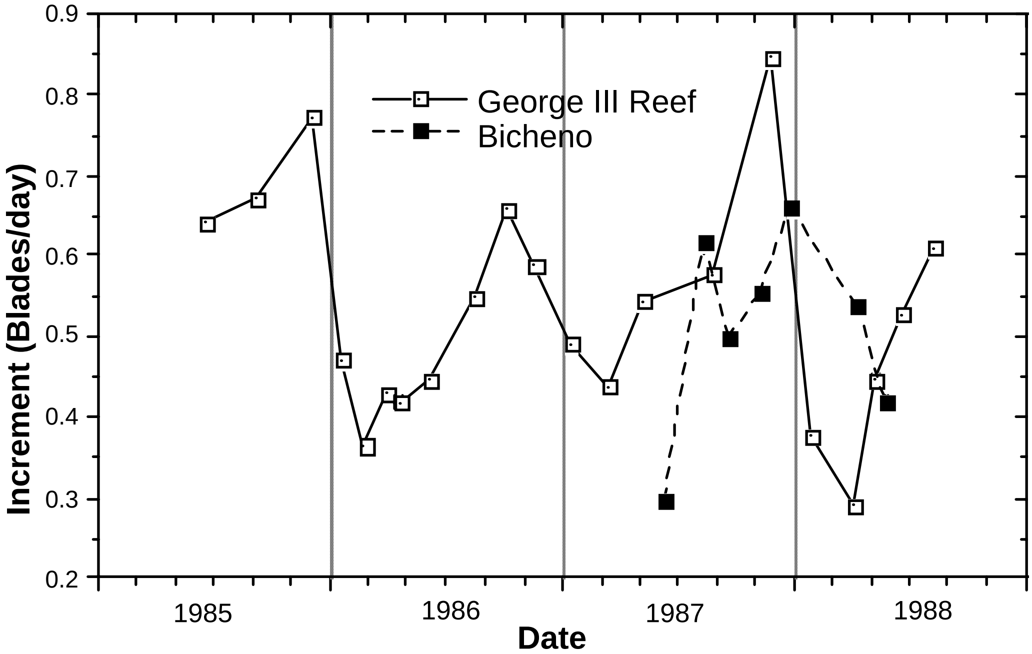
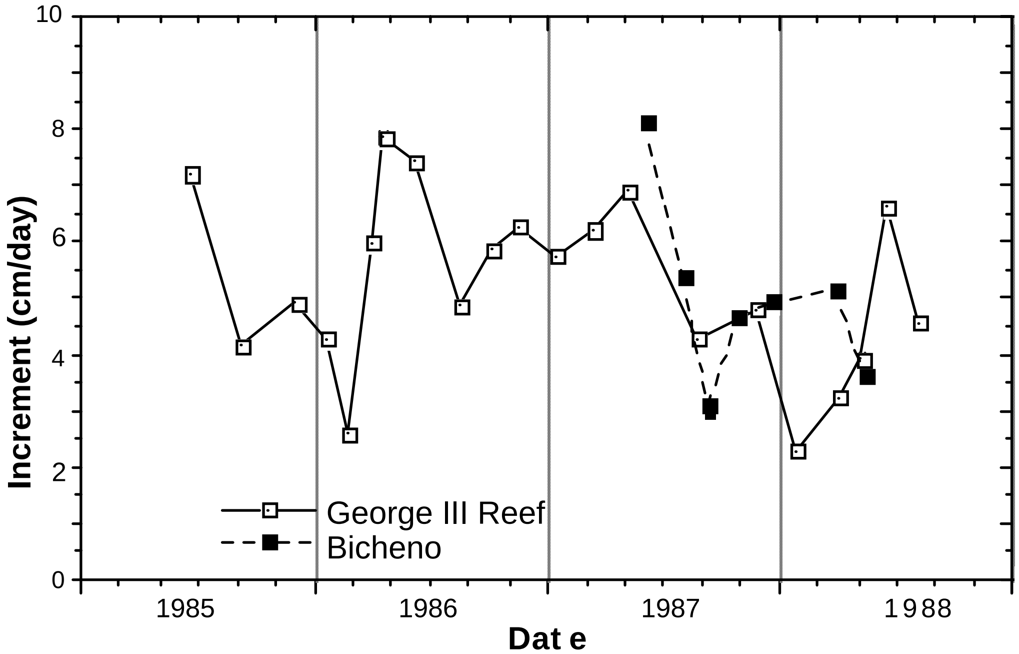


FIGURE Graph showing measured growth rates of *Macrocystis* plants measured as increment in length at two sites on Tasmania's coast. Each point is the average measurement of 15 fronds.



FACTORS AFFECTING THE ALGA'S DISAPPEARANCE

A number of explanations, some involving human interference with the marine environment have been put forward for the disappearance of *M. pyrifera*. These include:

¥ disturbing the substrate through dredging for scallops in the 1950's. This has resulted in the silting up of inshore reef areas that were formerly colonized by *M. pyrifera* forests. In California, germination of spores of *M. pyrifera* has been shown to be negatively affected by sediment.

¥ similarly *M. pyrifera* may be affected by the increasing sediment load in coastal waters as a result of land clearing and wood-chipping. Land clearing and wood chipping results in less binding and protection for top soils which are then more susceptible to runoff. These then end up in waterways and are dumped into the sea. This results in more suspended sediment in the water column, cutting light penetration and more sediment on the inshore reefs.

¥ increase in boat traffic which cuts off growing fronds. This is equivalent to harvesting which has been demonstrated to have minimal effect on healthy *M. pyrifera* beds when conducted in a controlled manner. However, when done on a continual basis and especially with beds that may be unhealthy for some reason will have a deleterious affect.

¥ the over-fishing of rock lobster which are believed to feed on sea urchins. This has led to an increase in sea urchins which then feed on *M. pyrifera.* In Canada and North America, a relationship has been postulated between crayfish and urchins whereby urchin numbers are controlled by crayfish. The heavy fishing pressure on crayfish has consequently resulted in an increase in the numbers of urchins. This has then bought about an increase in urchin barrens that have resulted from increased numbers of this animal. As in California, divers in Tasmania have observed urchin climbing *M. pyrifera* plants and pulling them down to the substrate where they are eaten. Urchin barrens are the ocean equivalent of deserts on land.

¥ the commercial harvesting of String Kelp have also been put forward as potential reasons for the declining populations. A company established in the 1960's was established to harvest *M. pyrifera* for alginates. Declining levels of this alga at the time contributed to the collapse of this company in the early seventies. Levels of the alga have since approached former levels, but some areas, a number of which are close to the site of the former alginate factory, have never recovered. Harvesting of *M. pyrifera* to feed juvenile abalone in developing abalone farms is minimal to nonexistent here in Tasmania.

¥ the recent introduction of *Undaria pinnatifida* (a Japanese seaweed thought to have introduced through ballast waters) which occupies a similar ecological niche to *M. pyrifera* and is thus a potential competitor. In areas where *Undaria* occurs, the alga can form mono-specific stands. The plant can grow up to two meters in length and so effectively 'smother' the reef bottom. This will affect not only *M. pyrifera* but other local plants and animals in an unknown manner.

¥ there are strong indications that *M. pyrifera* populations have been declining in conjunction with the warming of coastal waters. Maximum annual temperatures and salinities of eastern Tasmania's coastal waters have been rising as measured by CSIRO oceanographers since the 1940's due to more frequent incursions of the warm, nutrient depleted waters of the East Australian Current (EAC) adjacent to Tasmania's coast. In 1987, levels of *M. pyrifera* on Tasmania's east coast were at a minimum (pers obs). This coincided with very warm waters.

In California, *M. pyrifera* beds have shown to be affected by El Nino. The driving force behind the appearance of the EAC is not known but may be related to El Nino. At present it appears to be affected by the duration and intensity of the westerly winds which drive cooler waters up the east coast of Tasmania. These may tie into a 10 year cycle, the mechanism for which is not yet known. The kelp's poor health is most likely to be caused by the nutrient depleted nature of these waters than the warmth of the water.

MACROCYSTIS AS HABITAT

The presence of forests of *Macrocystis pyrifera* on the coast enhances the productivity of an area and increases niche availability. Some Tasmanian abalone divers and crayfishermen believe the beds of *Macrocystis* are better areas for production of their respective prey.

Macrocystis plants have been measured at up to 30 m long and form an upper canopy over other smaller algae. By doing so they increase habitat complexity and provide a refuge for a greater number of fish and invertebrate species and are possible nursery areas. The decline in Stripy Trumpeter and Real Bastard Trumpeter stocks from Tasmania's east coast may be partly attributable to the decrease in stocks of *Macrocystis*.

Macrocystis is also a very productive plant and likely to be important in developing a detritus based food web. Urchin divers claim their best catches come from within *Macrocystis* beds. The decline in levels of the alga in Tasmania may have lowered the available stocks of abalone and urchin which feed on the alga.

Macrocystis may also play a role in trapping larvae of important commercial species such as lobster and abalone. In urchin barren areas there is little to prevent eggs and larvae from being swept off the reefs. The larger seaweeds also provide important protection from predators for juvenile species. Research also needs to be conducted into plant and animal diversity in association with *Macrocystis* stands

The high productivity of this alga and the ability to increase habitat complexity means that this algae is potentially an important component of the local marine ecosystem. This underlines the potentially large effect of the disappearance of this alga.

If the loss of *M. pyrifera* is related to an activity which is reversible such as boating traffic or fishing practises then these can be mitigated and the populations of *M. pyrifera* encouraged to return.

KELP RECOVERY PROGRAM

The resilience of kelp beds to stress factors such as warmer waters can be enhanced by increasing the stock levels.

Recovery of populations in years when water temperatures are lower may be influenced by recruitment problems. If there are no adults to recruit from then populations will not recover. When water temperatures are lower it may be possible to re-establish *M. pyrifera* by transplanting. This has been successfully done in California in the wake of sea urchin plagues. This could be an ongoing program in Tasmania if the worth of these forests from an intrinsic and commercial point of view justified this course of action. Growing from spores is also an option but normally requires laboratory facilities.

SITE DESCRIPTIONS

For these projects, there are presently (July 1998) seven sites in the Derwent region, and three sites at Binalong Bay (see attached maps). These consist of donor and recipient sites and controls for each of these. Sites are comparable in depth and substrate. The control sites are used to compare the effects of transplanting with areas that have not been disturbed through this project..

Each site will be surveyed by suitably qualified marine biologists before tranplants occur and at regular intervals thereafter.

Surveys will record:

- percentage cover of *Macrocystis* (including the density of plants);
- percentage cover of major macroalgal species including total cover;
- density of urchins (other invertebrates?) and;
- number and species of fish.

Each transect should be videoed at the same time as it is surveyed.

TRANSPLANT METHODOLOGY

The total number of *Macrocystis* plants taken from a donor area will be less than 10% of the total population in that area.

Volunteer divers will collect the *Macrocystis* plants from the donor site, from an area as described by the researchers in relation to the permanent transect lines (Derwent Estuary) or mooring markers (Binalong Bay. Plants will preferably be less than 2m long.

Transplantation of plants should take place between autumn and spring (latest early December) to give the plants the best chance of survival. Plants should consist of juveniles from 10- cm in length to mature plants with up to one-five fronds. Once gently wedged off the rocks, transplants should be taken to the surface and kept moist ad cool. This may be by keeping in low densities in water filled tubs or by being ket cvered with damp hessian. Ideally they should be re-planted the same day and te following day at the latest.

Plants should be gently returned to the water at transplant sites. Plants can be secured using elastic bands ot bricks (see Fig).

CULTURE

Culture of *Macrocystis* is an option. Young plants can be seeded on to small rocks and then dispersed from the surface into the sea. This method will be trialled.

METHODOLOGY

Sporophylls are harvested from matue plants. These are kept in cool seawater once bought to the surface. Spore release should be initiated in a clean cool environment. To initiate spore release, sporophyll surfaces were wiped clean and placed in a 10% solution of the antiseptic Betadine in seawater for 10 minutes to surface sterilize, rinsed in sterilized seawater, wiped clean again and left in a cool place for 1.5 hours. They were then placed in seawater (sterilized 0.5-1 litre containers). Spore release will be effected within 1-2 hours.

This spore solution can be used to innoculate many litres of sterilized, nutrient enriched seawater. Ideally spore densities on the bottom should be calculated to give a density of approximately 1000 gametophytes per 5 x 5 cm^2 of substrate. Sea water should be exchanged approximately every two weeks. Under ideal conditions, new plants will become evident at 4-6 weeks.

Ideally, the seawater solution should consist of 0.2µm filtered sterilized (autoclaved) seawater, PES enriched with iodine. Heat sterilized seawater may be substituted, with ammonium phosphate (common fertilizer) added at a rate to give comparable concentrations of N and P.

For fastest growth, the seawater should be kept at 15^{o}C.

OUTCOMES

A report will be provided by the researchers after each survey detailing results. Recommendations should be given by the researchers as to the number of plants for transfer, where they are to come from and where they are to go to.

A final report giving the success of the project and further follow-up options.

Appendix 2

Macrocystis Culture Handbook

NOTE THAT SEACARE INC HAS COMPILED THIS HANDBOOK WITH THE ASSISTANCE OF NHT FUNDING. PLEASE CHECK WITH SEACARE BEOFRE COPYING OR USING ANY OF THE INFORMATION CONTAINED WITHIN.

INSTRUCTIONS for culture of *Macrocystis* spp.

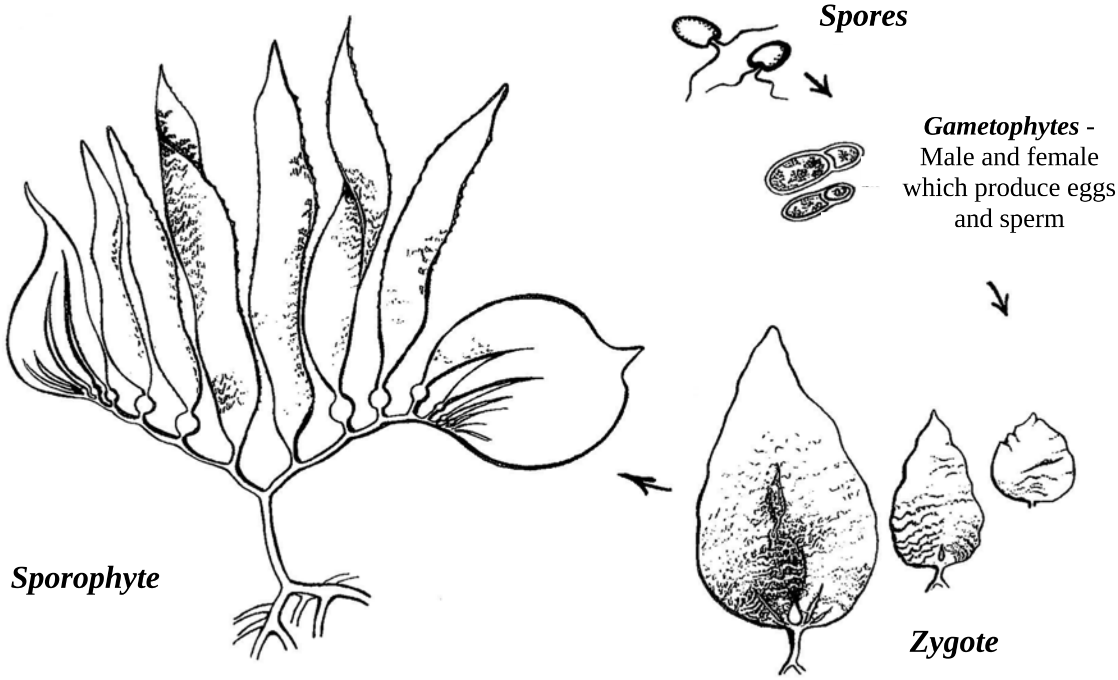
The aim of this handbook is to present methods for culture of *Macrocystis* species so that community groups or other interested parties can 'grow their own'. This handbook follows on from and should be read in conjunction with the '*Macrocystis* Transplant Handbook'.

INTRODUCTION

Similar to ferns, the lifecycle of *Macrocystis pyrifera* has two phases. One is the large plant we can see; the second is a microscopic filamentous phase.

The large plant (sporophyte) gives rise to motile spores. The spores are released from specialised blades near the base of the plant. These blades are readily identifiable, as they do not have vesicles (bubbles/bladders) at their base near the stem.

In Tasmania, plants have sporophylls all year round so are likely to have the capacity to release spores throughout the year although the quality and quantity is likely to vary with season. The spores are very small with a diameter of less than 10③m. 'Ripe' sporophylls are identifiable by a raised surface, which has a furry appearance and is darker in colour, but lighter and tattered where spores have been released.



Studies in California show spores can be motile for as much as 24 hours. Once landed on suitable substrate, the spores develop into microscopic filamentous plants called gametophytes. Gametophytes are believed to be hardier than the parent plants, able to resist adverse conditions such as higher temperatures and low nutrient concentrations.

Studies in closely related species have revealed that gametophytes can survive lengthy periods (more than 8 months) without light. This means that they can easily be transported within ship's hulls such as for the introduced alga *Undaria pinnatifida*. A study currently (1999) underway in Mexicois examining the potential for gametophytes of *Macrocystis pyrifera* to remain dormant for a number of years until conditions are suitable and then give rise to the parent plants. This may explain why beds appear to spring spontaneously in areas where there have been none previously for a number of years.

The gametophytes produce gametes – a motile male spore (approx. 10③m in diameter) and a larger female egg. Because gametophytes are either male or female, chances for fertilisation success is enhanced when the male and female gametophytes are in close proximity. This means that fertilisation success is usually greatest close to the parent plant/plants as the further away from the parent plant, the further the gametophytes are likely to be from each other. They rarely produce plants further away than 5m from the source plant.

CULTURE

One of the primary aims when culturing *Macrocystis* and other algae from spores is to maintain conditions that are as clean and sterile as possible. This limits the chances of other algae and microorganisms being initiated within the cultures thus competing for space, light and nutrients.

Culture Premises

Culturing should be done where there is plenty of bench space. This area should be cleaned prior to and during spore release. Wiping with alcohol (70% isopropanol or ethanol) or a chlorine solution (approx. 400ppm available chlorine) ensures minimal possible accidental infection from either other algae or bacteria. Where the intended culture areas are close to the coast or flowing seawater – extra care should be taken, as some algae can be transported through the air. Ideally all work should be done in a laminar flow cabinet. This ensures there is minimal risk of infection from air borne contaminants.

Containers for culture

Glass culture vessels are the easiest to keep clean, however as the intention is to grow the alga in large quantities, plastic and polyetheylene containers can be used. I am currently using cheap 15l plastic see-through vessels with lids obtained from a discount shop, and similar can be found at the local supermarket. The advantage of having see-through lids is that is possible to provide light for growth whilst minimising the chances of infection through airborne algae; and loss of seawater through evaporation; while allowing light through for growth of the algae.

Sterilisation of seawater

Common practice for sterilisation of seawater is to pass the seawater through successively finer filters with the aim of excluding all particles greater than 0.2 - 0.5 ③m in diameter. This effectively keeps out all organisms with a cellular structure ie phytoplankton and potentially herbiverous zooplankton without significantly altering the chemistry of the seawater.

Other methods for the sterilisation of seawater include autoclaving, boiling, the addition of chlorine and then neutralisation with sodium thiosulfate and exposure to UV light (up to 1200 W).

Heating to 73^{o}C usually is effective for removing algal contaminates, heating to 73^{o}C on three successive days with intermittent cooling at room temperature usually kills all bacteria.

Sterilisation of containers and other gear

After washing in a bio-friendly detergent, containers and other gear can either be autoclaved, heat treated, soaked with a chlorine solution (approximately 400 ppm available Chlorine), microwaved or exposed to UV light to sterilise.

<u>Chlorine:</u> The chlorine solution can be made from the Chlorine available for treating swimming pool water or common bleach used for cleaning in-door household surfaces. Chlorine treated articles should be air-dried allowing Chlorine to escape before use.

Autoclaved: 121°C in pure saturated steam at 15lb/in^2 above atmospheric pressure for at least 10 min.

Heat treatment: in a hot air oven: 2 hours at 160°C.

UV Treatment: surfaces require exposure to a 20-40W lamp. Media should be put into quartz test tubes and irradiated for 2-4 hours. Note that UV radiation can cause severe eye damage, therefore protective glasses should be worn.

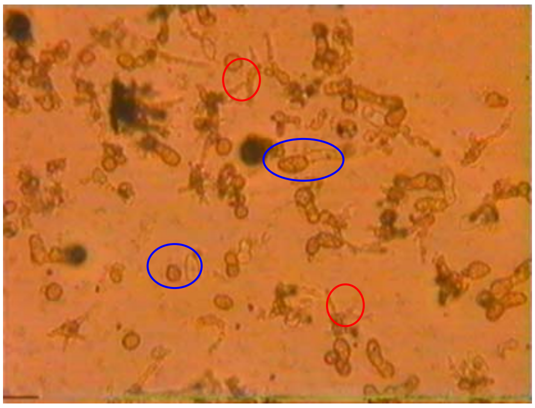
Microwave: Place containers and/or other gear in microwave for 5 min on 'High'.

Sporophyll collection
Sporophylls are collected from the base of adult plants. They should be placed in seawater and kept cool as possible (5-10°C) immediately after collection, particularly if spore release is not to be effected on the same day.

Spore release
This should be done as soon as possible after collection of plants. Outer surfaces of the sporophylls should be sterilised to minimise the chance of introduction of other species that epiphytic or growing. This is done by wiping the outside surfaces with an antiseptic solution which may be either a 10% Betadiene (hospital antiseptic) or an alcohol (70%) solution.

The sporophylls are then kept in a cool dark place (such as a fridge) for approximately two hours. This dehydrates the sporophylls. The sporophylls are then introduced to sterilised seawater. Ensure temperature is less than 18°C. Spore release will then occur over the next 30 minutes. Spores may be evident in the solution as a murkiness or a light brown discolouration.

If a microscope and a graticuled slide are available, spore density can be calculated. Spore densities per area substrate that are generally between 2 and 10 / mm^2 should be aimed at to prevent overcrowding. Otherwise a ‘stab in the dark’ may be necessary. Spore solutions that result in clouding of the water in inoculated solutions should be avoided as this indicates high spore densities and the possible introduction of foreign materials, which may enhance bacterial production.



Pictures taken at the Marine Discovery Center showing gametophytes (female:- blue circles and male:- red circles) above and sporophytes (beginning of large plants) below.

Culture solution

Most culture solutions for macroalgae include nutrients in proportions that are variations of what is known as a 'PES' recipe (Provosali's Enrichment Solution). This is a combination of chemicals such that nutrients critical to the growth and well being of the algae are present. Without laboratory facilities these solutions can be difficult to formulate. Success in hatcheries in growing microalgae has been obtained using two products commonly used to fertilise land plants. These are Aquasol and chelated iron. The Aquasol is added at the rate of 50g/1000litres and the chelated iron at a rate of 6g/1000litres.

The growth medium should be changed weekly for growing plants

Substrate

A substrate for growing plants to attach to that is convenient for transplanting into the field should be used. Commercial culture of similar algae in south east Asian countries is done on cotton twine. The cotton twine is wound on to a frame that is then placed into the stock solution. Sections of the twine are cut off afterwards and placed within rope twists for placement in the field. Other substrates that could be considered are sections of PVC pipe and rocks or gravel that may be freely distributed in the field. Remember that to optimize chances of success, these should be sterilised as above.

Coverslips can be included on the bottom of the containers so that development of the gametophytes can be monitored. These are introduced prior to innoculation with the spores (remember they have to be sterilised as well) and on a regular basis, can be individually sacrificed for examination of gametophytes. Measurments can be done on the gametophytes to determine growth rates and maturity. Coverslips can be removed with fine forceps (remember to sterilise).

Aeration

As the algae get larger they will require circulation of the medium mostly to ensure adequate supply of nutrients to all parts of the plant. The currents ensure proper development of the plant so that it is more hardier and able to resist adverse environmental conditions such as wave action. Currents also ensure proper development of the holdfast so the plant can properly attach. For *Macrocystis*, in ideal circumstances the gametophytes may produce fertilised gametes within 2-4 weeks of innoculation. Introduction to a circulating medium should occur after 4-6 weeks. Circulation of the medium can be provided with an air pump and stone. Remember to also sterilise this before introduction to the culture medium.

Temperature
Growing temperatures for *Macrocystis* gametophytes should be within 10-18^{o}C. Temperatures over 22^{o}C are likely to result in mortality. Cooling units or cooling baths are required if temperatures are likely to get higher than 20^{o}C.

Light
Common light levels quoted for the growth of gametophytes range up to 4000 lux. Light levels from neon lights are unlikely to result in photoinhibition so the more light the better. Light from multiple (>2) flourescent tubes from a maximum distance of 30cm will result in adequate light levels.

Best growth is obtained from a 12/12 light: dark regime. Continuous light (or dark) is not recommended. A common household timer can be used to provide this.

Juveniles (small sporophytes) growing at the base of a concrete tyre with sub surface buoy marking the site at Cape Paul Lemenon. Plants growing on gravel had been placed here a few weeks previously.

GLOSSARY

Autoclave - Equipment for heat - steam treatment for sterilization

Culture solution - for plants from the marine environment this will be in a seawater base with added nutrients to provide best plant nutrition.

Requirements for innoculation and culture.

Betadiene (obtainable from chemists) sterilizing solution
Containers for spore release - sterilised
Containers for growth of the alga - sterilized
Sterilised seawater
Tweezers suitable for handling clean sporophyll blades
Tweezers suitable for picking up coverslips/microscope slides
Tissues/paper towels for cleaning surfaces
Sterilising solution for working surfaces
Clean workspace
Sporophylls
Lights - 2 x 30W flourescent sufficient
Cool place for culture containers ($<18^oC$)
Aerators - sterilised for growth in cultures after 4 weeks.