4. VECTORS THAT MAY TRANSFER THE WEED TO NEW LOCATIONS WITHIN NSW

The generation of fragments and their subsequent attachment and regrowth are accepted as being the processes by which invasive *C. taxifolia* reproduces, disperses and establishes new infestations (Belsher and Meinesz 1995; Ceccherelli and Cinelli 1999a; Millar 2002). We identified several mechanisms, both natural and human associated, that might generate fragments from established patches of *C. taxifolia* and which could assist in the transportation of those fragments to other sites, either within the same bay or estuary or to more distant locations (Table 4.1).

Table 4.1. Potential mechanisms for generating and transporting fragments of *C. taxifolia* and their relative importance in NSW estuaries.

Vector	Places of greatest risk	NSW examples (as at January 2004)
1. Human mediated		
Commercial fishing nets	Estuaries where commercial hauling is undertaken	Pittwater, North Sydney Harbour. Other estuaries with *C. taxifolia* are now closed to commercial fishing
Recreational fishing gear (lines or nets)	Estuaries that are popular fishing locations	Most currently infested sites
Diving equipment (e.g. wetsuits, fins)	Estuaries that are popular swimming or spear-fishing locations	Lake Macquarie, Narrawallee Inlet
Boat propellers or hulls, water skis, trailers	*Sites adjacent to boat ramps, permanent mooring sites or marinas*	Lake Conjola, Port Hacking
Anchors / anchor chains	Sheltered bays that are popular anchoring locations for casual use	Most currently infested sites except Narrawallee
Release from aquaria	Sites where aquarium stores or public aquaria hold *C. taxifolia* and discharge seawater directly to the sea	None known. The possession of *C. taxifolia* in the coastal fringe is now illegal in NSW
Aquaculture	*Estuaries where oyster farming is done*	Burrill Lake, Lake Conjola, Botany Bay
2. Natural		
Ocean currents, tides & wave action	Large, open areas with considerable wave fetch or strong currents	Lake Macquarie, Botany Bay, Western Lake Conjola (wind); Narrawallee (tidal currents)

There are several natural vectors that may aid the fragmentation and translocation of *C. taxifolia*, such as storms (see Chapter 3.1.1), currents, disturbance of the seafloor by feeding animals such as fish and rays or the feeding activities of herbivores such as sacoglossan molluscs that are eating the alga (Coquillard *et al*. 2000; Thibaut *et al.* 2000; Thibaut *et al*. 2001). These natural processes are most likely to contribute to spread within a location such as an estuary. These vectors become increasingly important as the amount of *C. taxifolia* at a site expands, and they may overshadow the importance of human associated vectors when infestations cover large areas such as in Lake Conjola and Botany Bay in NSW (see Chapter 2). Natural processes associated with water movement, such as the ripping out of plants, rapid transport of fragments or the burial of plants under sediments (e.g. Glasby *et al*, in review) may occur periodically (e.g. storms) or on a more regular basis where there are strong tidal currents (eg in Narrawallee inlet. Spread to a new location could potentially occur if fragments are washed out to sea, carried by currents along the coast, and then swept into a new bay or estuary. However, this risk is considered slight in NSW (Millar 2002). Vectors associated with human activities are considered much more likely to cause the transportation of fragments to more distant locations.

Caulerpa taxifolia is a popular marine aquarium plant throughout the world, including Australia, and it has been sold for many years within the aquarium industry. It appears that *C. taxifolia* has been introduced into several waterways in the Mediterranean, California and Australia, accidentally or otherwise, from aquaria. Plants may escape directly from large aquaria with flow-through seawater systems (eg aquarium shops, public display tanks, research institutions) where these are situated immediately adjacent to coastal waterways. Introductions may also occur if the unwanted contents of smaller aquaria that contain fragments of *C. taxifolia*, such as household fish tanks, are tipped into brackish creeks, estuaries or sheltered coastal embayments.

Many commercial activities on waterways infested by *C. taxifolia* can be significant in generating and spreading fragments of the alga. These include commercial fishing (eg shore-based hauling, trawling in estuaries), dredging or sand extraction, building or maintenance of foreshore structures such as wharves, jetties or boat ramps and the deployment of channel markers, boat moorings or other floating devices that need to be anchored to the seafloor. These mechanisms are likely to be most important where infestations of *C. taxifolia* occur adjacent to large urban areas or near commercial ports. Examples in NSW are Pittwater, Sydney Harbour, Botany Bay and Port Hacking (see Figure 1.1).

Finally, there are human leisure activities that may generate, trap and transport fragments of *C. taxifolia*, including passive pursuits such as swimming, snorkelling or diving and more active pursuits such as boating, water skiing, anchoring or recreational fishing. These mechanisms are likely to be most important where infestations of *C. taxifolia* occur in smaller or more isolated areas. Examples in NSW are the southern lakes such as Conjola, Burrill and Narrawallee (see Figure 1.1). When fragments of *C. taxifolia* removed from the water are kept moist for several days (eg in fishing nets or the anchor wells of boats), this provides a potential vector for transportation to another estuary. It is activities associated with human leisure pursuits in these southern lakes that are investigated in this chapter in an attempt to quantify their likely contribution to the spread of *C. taxifolia.* These investigations formed the basis of an Honours project at the University of Wollongong (see West 2003).

4.1. Patterns of *C. taxifolia* fragmentation

Spatial patterns of abundance and biomass of fragments were investigated within Lake Conjola and Port Hacking, between locations with different levels of anthropogenic activity. The hypothesis was that there would be more fragments in locations with high levels of anthropogenic activity.

Locations, approximately 900 m^2 and with > 90% cover of *C. taxifolia,* were classed as having either ‘high’ or ‘low’ anthropogenic activity, based on a series of observations. Locations designated “high activity” locations were adjacent to boat ramps and/or were observed to have more human activity (boats, fishers and swimmers) compared to low activity locations. At each location, *C. taxifolia* fragments were collected in 10 replicate quadrats and their abundance and biomass estimated. The number of locations that were infested with *C. taxifolia* and the intensity of anthropogenic activities were different between Lake Conjola and Port Hacking, therefore different experimental designs were used for each estuary.

At Lake Conjola, three locations of high activity were compared to three locations of low activity. High and low activity locations were sampled within Lake Conjola on two occasions, March and June 2003. The hypothesis that the abundance and/or biomass of fragments were significantly larger at locations of high compared to low anthropogenic activity was tested using a three factor ANOVA. Interactions of Time x Location (Activity) and Time x Activity were examined first. When there were no significant interactions, the main effects of Activity and Time were then examined. Post-hoc pooling or elimination of factors was used when possible (when $p > 0.25$) to construct an appropriate test.

At Port Hacking, one location of “high activity” was compared to two locations of “low activity” in March 2003. This design was necessary because few locations in Port Hacking were infested with *C. taxifolia*. Only one location in Port Hacking had much more anthropogenic activity compared to other locations invaded by *C. taxifolia*. Because the experiments in Port Hacking involved the comparison of one location of high anthropogenic activity to two locations of low anthropogenic activity, asymmetrical analyses were used.

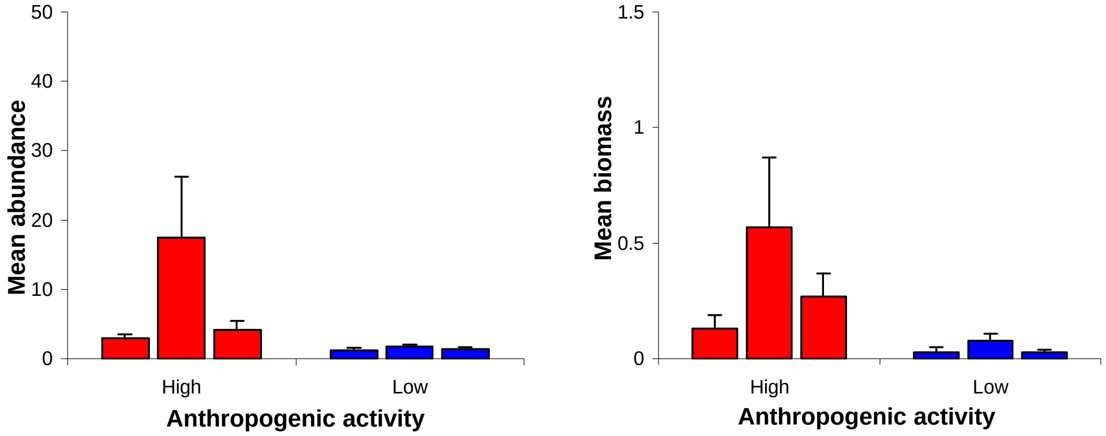
4.1.1. Results

In Lake Conjola, the mean (± s.e.) abundances of fragments of *C. taxifolia* (per 1250 cm^2 quadrat) in the locations of high and low anthropogenic activity were 8.1 (± 3.1) and 1.5 (± 0.2) respectively, on the first sampling occasion, and 18.7 (± 3.8) and 7.9 (± 1.0), on the second sampling occasion.

There were significantly more fragments of *C. taxifolia* in locations of high anthropogenic activity compared to locations of low anthropogenic activity, on both sampling occasions (Figure 4.1; Table 4.2). Abundances of fragments were also more variable among locations of high anthropogenic activity than locations of low anthropogenic activity on both sampling occasions (Figure 4.1; Table 4.2). There were no significant interactions between any of the factors tested. Patterns of difference and variation remained similar for both sampling occasions, although overall there were significantly more fragments on the second sampling occasion (Figure 4.1; Table 4.2).

Similar trends in patterns of differences were observed for biomass. Mean (± s.e.) biomass (g dry weight) of fragments of *C. taxifolia* (per 1250 cm^2 quadrat) in the locations of high and low anthropogenic activity were 0.33 (± 0.12) and 0.05 (± 0.01) respectively, on the first sampling occasion, and 0.64 (± 0.12) and 0.17 (± 0.03), on the second sampling occasion. However, there were no significant differences in the biomass of *C. taxifolia* fragments between locations of high anthropogenic activity compared to those with low anthropogenic activity. There was more variability among locations of high anthropogenic activity compared to low (Figure 4.1; Table 4.2). There were no significant interactions between any of the factors tested. Overall, there were significantly higher biomasses of *C. taxifolia* fragments on the second sampling occasion, but patterns of difference and variation remained similar for both sampling occasions (Figure 4.1; Table 4.2).

A.



B.

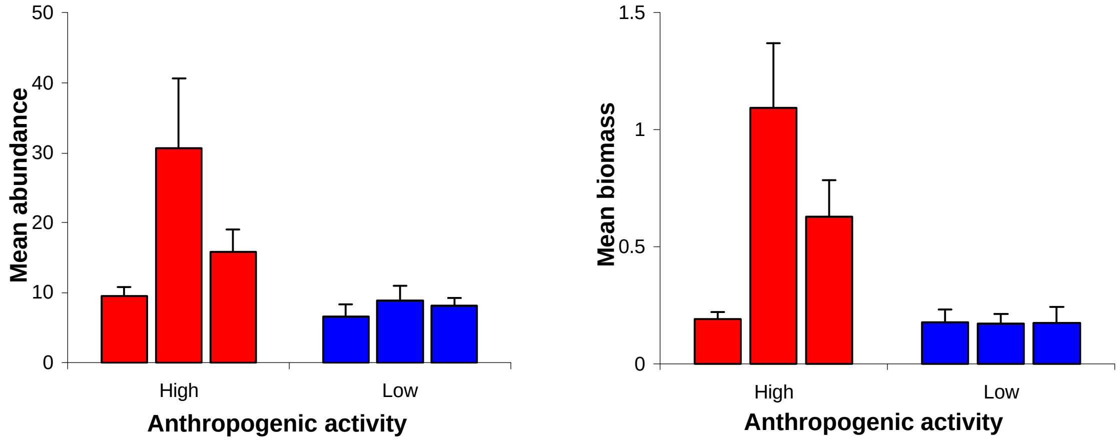


Figure 4.1. Mean (+s.e.) abundance (left) and biomass (g dry weight) (right) per quadrat, of *C. taxifolia* fragments sampled in Lake Conjola at three locations with high anthropogenic activity and three locations with low anthropogenic activity, on two sampling occasions, (A) 26th March 2003 and (B) 20th June 2003. n=10.

Table 4.2. Results of ANOVAs and SNK tests, for testing hypotheses about patterns of distribution of abundance and/or biomass of *C. taxifolia* fragments in Lake Conjola. Note: F-ratios in bold were calculated after non-significant (P>0.25) interactions were pooled or eliminated to test for main effects. ns=not significant; * <0.05; ** <0.01; *** <0.001.

Source	***df***	**Abundance**			**Biomass**			**F versus**
		MS	**F**		**MS**	**F**		
Time	1	34.04	161.79	***	0.75	14.88	*	Ti x Lo(Ac)
Activity	1	18.15	**8.77**	*	1.51	**4.77**	**ns**	**Lo(Ac)**
Location(Ac)	4	2.07	9.83	**	0.31	6.28	***	Ti x Lo(Ac)
Ti x Ac	1	0.03	0.13	ns	0.09	1.74	ns	Ti x Lo(Ac)
Ti x Lo(Ac)	4	0.21	0.37	ns	0.05	0.95	ns	Res
Residual	108	0.57			0.05			
Total	119							
Transformation			Ln (X+1)			Ln (X+1)		
Cochran's			ns			**		
SNK								
Time		T1<T2			T1 <T2			
Activity		High>Low						
Location(Ac)		High: L1=L3<L2 Low: L1=L2=L3			High: L2>L1; L2=L3; L2=L1 Low: L1=L2=L3			

In Port Hacking, the mean (± s.e.) abundances of fragments of *C. taxifolia* (per 1250 cm^2 quadrat) at locations with high and low anthropogenic activities were 49.3 (±4.9) and 8.8 (±1.1), respectively. However, because the control locations were significantly different from each other and the analysis had very few degrees of freedom, a significant difference between high and low activity could not be detected (Figure 4.2; Table 4.3).

The mean (± s.e.) biomass (g dry weight) of fragments per quadrat at the locations with high and low anthropogenic activity in Port Hacking were 1.79 (±0.34) and 0.10 (±0.01), respectively. The biomass of fragments was significantly larger at the location with high anthropogenic activity compared to the two locations with low anthropogenic activity (Figure 4.2; Table 4.3).

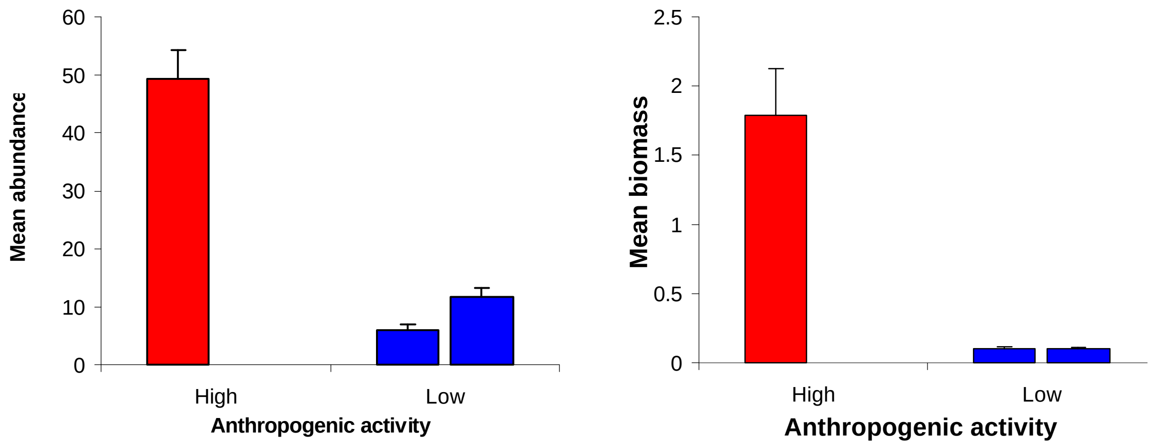


Figure 4.2. Mean (+s.e.) abundance (left) and biomass (g dry weight) (right) per quadrat of *C. taxifolia* fragments sampled in Port Hacking at one location with high anthropogenic activity and two locations with relatively low anthropogenic activity, sampled on 20th March 2003. n=10.

Table 4.3. Results of asymmetrical ANOVAs for testing hypotheses about patterns of distribution of abundance and/or biomass of *C. taxifolia* fragments in Port Hacking. ns not significant; * <0.05; ** <0.01; *** <0.001.

Source	***df***	**Abundance**			**Biomass**			**F versus**
		MS	**F**		**MS**	**F**		
Location	2	10.77			2.55			
Impact vs Control	1	19.44	9.31	ns	5.09	50921.00	***	B. Cs
Between Cs	1	2.09	13.09	**	0.00	0.00	ns	Res
Residual	27	0.16			0.04			
Total	29							
Transformation		Ln (X+1)			Ln (X+1)			
Cochran's		ns			**			

4.2. Generation of *C. taxifolia* fragments by boat propellers

4.2.1. Methods

Two manipulative experiments were done to examine the impact of boating activity on the creation of *C. taxifolia* fragments in Lake Conjola. The first experiment was done in June 2003, to test the hypothesis that the movement of boats creates fragments of *C. taxifolia.* Three 30m x 1m transects were haphazardly positioned approximately 10m apart in shallow water (<1m deep) in a dense bed of *C. taxifolia*. Abundance (total number) and biomass (dry weight) of fragments were estimated in each of six randomly placed 25cm x 50cm quadrats along each transect (Figure 4.3). A small motorboat, similar to those extensively used in the lake, was then driven along one transect. This transect was defined as the 'boat' impacted transect, while the other two without boating activity were 'control' transects. Abundance and biomass of fragments were then estimated again in each of six distinct randomly placed quadrats along each transect. Positions of all quadrats in each transect were chosen before sampling to avoid the same place being re-sampled before and after. Asymmetrical ANOVAs were used to test for significant interactions of abundance and/or biomass of fragments between the boat and control transects from before to after the impact.

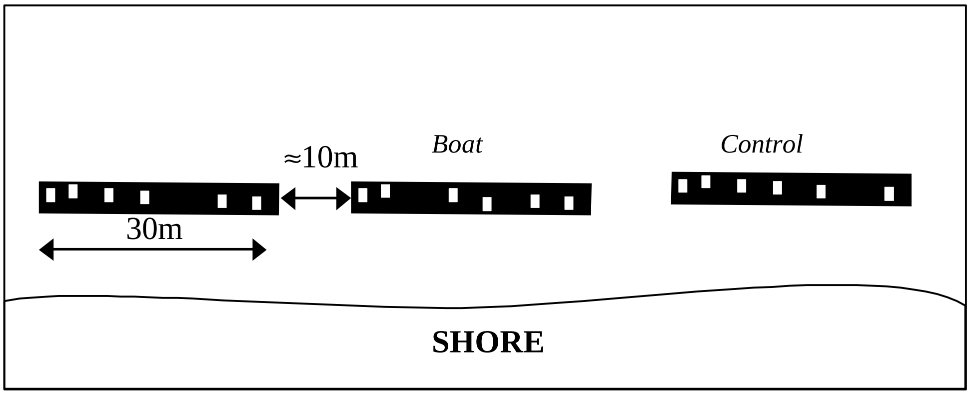


Figure 4.3. Diagrammatic representation of the experimental design to examine fragmentation along a boat-impacted transect and control transects on 4 June 2003. Fragment abundance and biomass were measured on each transect 'before' and 'after'.

A second experiment was done within a dense bed of *C. taxifolia* in Lake Conjola in September 2003. This experiment expanded on the previous experiment by testing for effects of boats at two different depths, shallow (approximately 1m) and deep (approximately 1.5 m). Four 30m x 1m transects, two 'boat' and two 'control,' were haphazardly positioned within each of these two depths (Figure 4.4). Abundance (total number) and biomass (g dry weight) of fragments were estimated in each of six replicate 25cm x 50 cm quadrats along each transect before and then again after the boat was driven along the 'boat' transects. Balanced, 4 factor ANOVAs were used to test for significant interactions of abundance and/or biomass of fragments between the boat and control transects from before to after the impact.

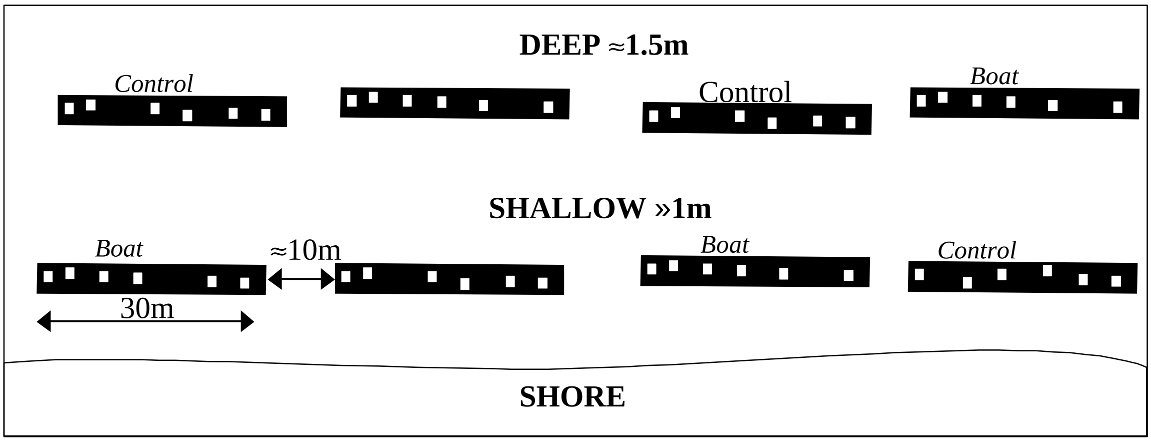


Figure 4.4. Diagrammatic representation of the experimental design to examine fragmentation along boat-impacted transects and control transects on 24th September. Fragment abundance and biomass were measured on each transect ‘before’ and ‘after’.

4.2.2. Results

In the first experiment (June 2003), the abundance and biomass of fragments were, on average, higher in the transect with boat activity (Figure 4.5). The abundance of fragments increased by 10 fold and the biomass of fragments increased by 4 fold. These apparent increases, however, were not always statistically significant when compared to control locations. Asymmetrical ANOVA tests showed that there was a significant ($p < 0.001$) increase in the biomass of fragments along the transect which had boat activity compared to control transects, but no significant difference in abundance of fragments (Figure 4.5; Table 4.4). The latter statistical test had few degrees of freedom, and caution should be used in interpreting this result (Table 4.4) because of low statistical power.

Results for the second experiment (September 2003) showed the same general patterns. Although there were small increases in the mean abundance of *C. taxifolia* fragments in the shallow transects after boating activity (Figure 4.6), there were no statistically significant increases in abundance at either depth (Table 4.5). Again, there were significant increases in biomass of *C. taxifolia* fragments from before to after boating activity in the boat transects compared to the controls at both depths (Figure 4.6; Table 4.5).

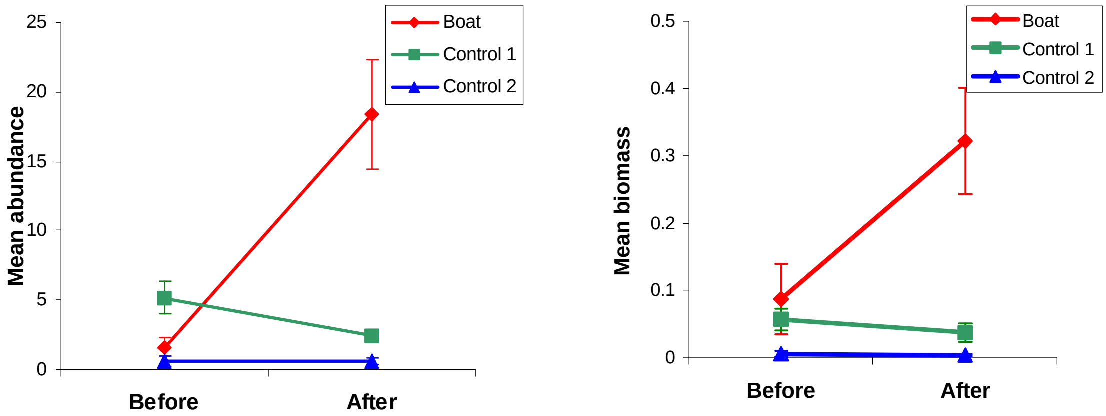


Figure 4.5. Mean (± s.e.) abundance (left) and biomass (g dry weight) (right) per 50x50cm quadrat of *C. taxifolia* fragments on one boat and two control transects before and after the impact of boat activity. Experiment was done in Lake Conjola on 4th June 2003. n=6.

Table 4.4. Results of asymmetrical ANOVAs for testing hypotheses about impact of boat activity on abundance and/or biomass of *C. taxifolia* fragments. Note: F-ratios in bold were calculated after non-significant (P>0.25) interactions were pooled or eliminated to test for main effects. ns not significant; * <0.05; ** <0.01; *** <0.001.

Source	***df***	**Abundance**				**Biomass**			
		MS	**F**		**F versus**	**MS**	**F**		**F versus**
Before vs After	1	0.46				0.055			
Location	2	1.12				0.032			
Impact vs Control	1	1.97				0.064			
Between Cs	1	0.28				0.001			
B v A x L	2	10.06				0.067			
B v A x I v C	1	19.70	46.00	ns	BvA x B.C.	0.130	25.12	***	Res
B v A x Between Cs	1	0.43	1.78	ns	Res	0.000	0.08	ns	Res
Residual	24	0.24				0.005			
Total	29								
Transformation		Ln (X+1)				Ln (X+1)			
Cochran's		ns				**			

Table 4.5. Results of ANOVAs for testing hypotheses about impact of boat activity at two separate depths on abundance and/or biomass of *C. taxifolia* fragments. ns not significant; * <0.05; ** <0.01; *** <0.001.

Source	***df***	**Abundance**			**Biomass**			
		MS	**F**		**MS**	**F**		**F versus**
Time	1	13.50			0.07			
Activity	1	63.38			0.16			
Depth	1	1204.17			5.07			
Transect (De x Ac)	4	53.94			0.19			
De x Ac	1	2.67			0.09			
De x Ti	1	0.04			0.05			
Ac x Ti	1	4.17	6.45	ns	0.14	10.56	*	Ti xTr (DexAc)
Ti xTr (De x Ac)	4	0.65	0.07	ns	0.01	0.31	ns	Res
De x Ac x Ti	1	2.04	3.16	ns	0.02	2.01	ns	Ti xTr (DexAc)
Residual	80	9.81			0.04			
Total	95							
Transformation		none				none		
Cochran's		ns				ns		

SNK

Ac x Ti	Boat: T1<T2 Control: T1=T2

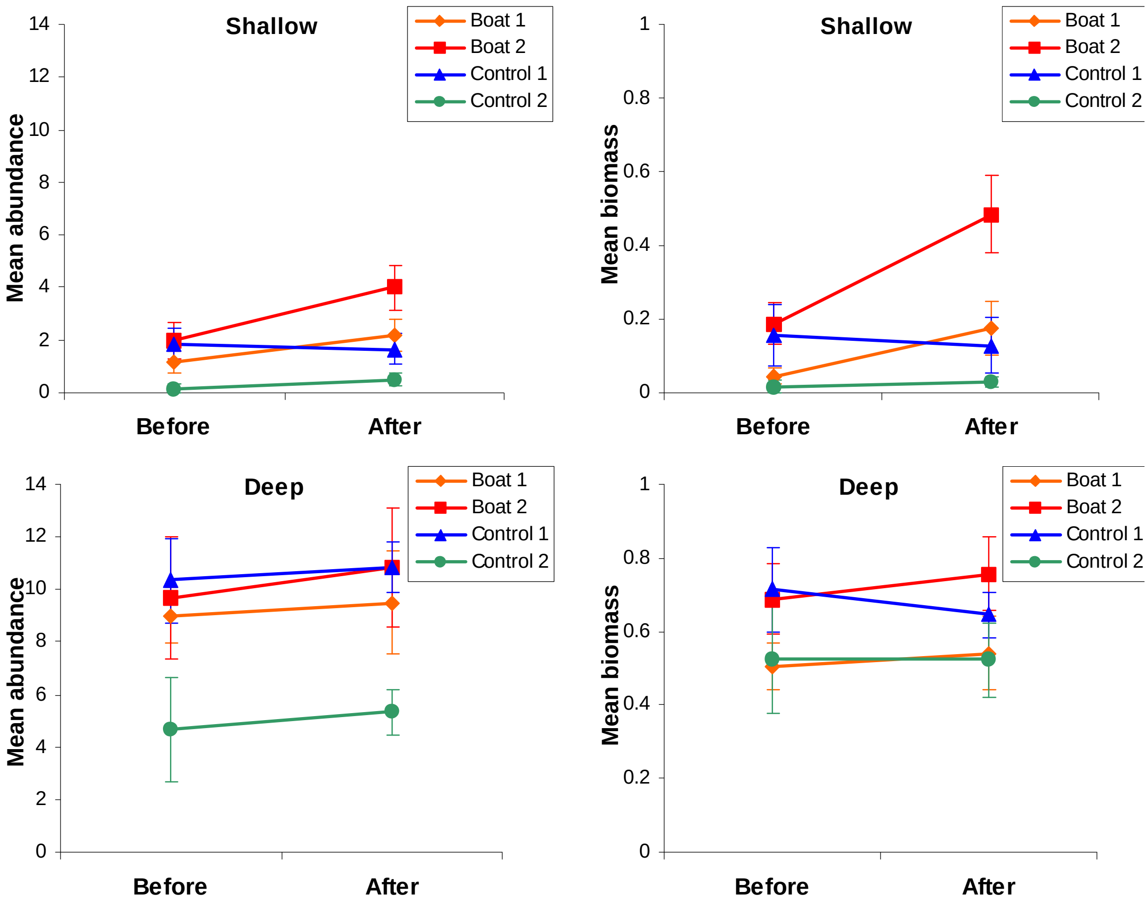


Figure 4.6. Mean (± s.e.) abundance (left) and biomass (g dry weight) (right) per 50x50 cm quadrat of *C. taxifolia* fragments on two boat and two control transects before and after the impact of boat activity, within two separate depth, shallow (upper) and deep (lower). n=6 replicates.

4.3. Generation of fragments by anchors

4.3.1. Methods

Manipulative experiments were done at Lake Conjola to test for differences in the amount of *C. taxifolia* removed from the lake by different types of anchors (rock or sand) and attachments (rope or chain) combinations (Plate 6). A total of six anchors (3 replicate sand anchors and 3 replicate rock anchors) were combined with four types of attachment (2 replicate ropes and two replicate chains). Each of the 6 possible combinations of anchor and attachment was lowered from the boat to the lake bottom and retrieved six times (i.e., there were 6 replicates for each trial). Each time, all fragments of *C. taxifolia* brought into the boat on the anchor and attachment were placed into zip-lock bags and taken back to the laboratory where the total biomass was determined. During the experiment the boat was allowed to drift over the bed of *C. taxifolia* to ensure that the anchor lowered was not on the same spot. To account for spatial and temporal variation, this experiment was done twice, May and July 2003, at two different locations. Four factor, partially nested ANOVAs were done to test for significant differences in the biomass of fragments associated with the type of anchor, type of attachment or combination of these.

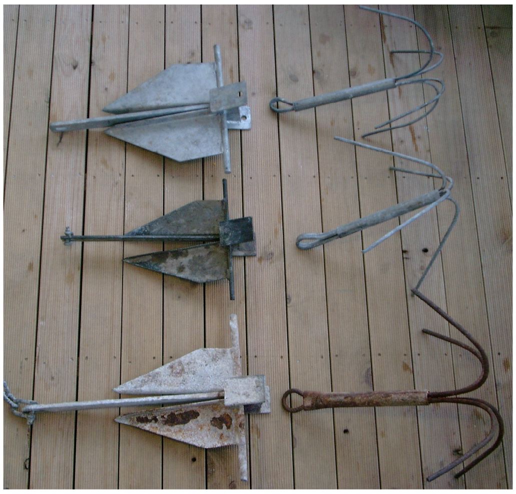


Plate 6. Sand and rock anchors used in experiments examining the effect of anchors. Two replicate lengths of chain and two replicate lengths of rope were attached, in separate trials, to each anchor.

4.3.2. Results

On almost all occasions during both runs of the experiment, several fragments of *C. taxifolia* were caught on the anchors themselves. There were also fragments caught on chain attachments but rarely on rope attachments. Both experiments gave very similar results. The quantity of *C. taxifolia* brought to the surface was quite variable. While there were, on average, greater biomasses of fragments on sand anchors compared to rock anchors (Figures 4.7, 4.9), these data were highly variable and differences were not significant (Table 4.6). Regardless of the type of anchor used (sand or rock), significant differences were found with respect to the type of anchor attachment (chain or rope); there was significantly greater biomass of fragments on chains compared to ropes (Figures 4.8, 4.10; Table 4.7).

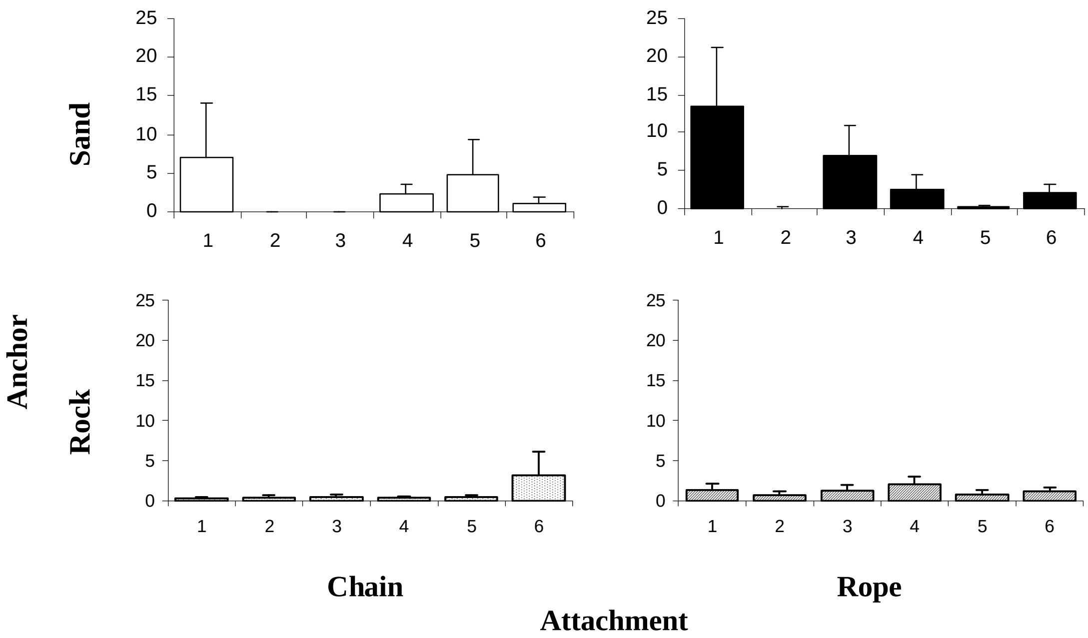


Figure 4.7. Mean (+s.e.) biomass (g dry weight) of *C. taxifolia* fragments removed from Lake Conjola on anchors. There were two types of anchor (with 3 replicates of each) and two types of attachments (with 2 replicates of each). This gives a total of 6 treatments along the x- axis. Experiments were done in Lake Conjola on 27th May 2003. n=6 trials with each combination of anchor and attachment.

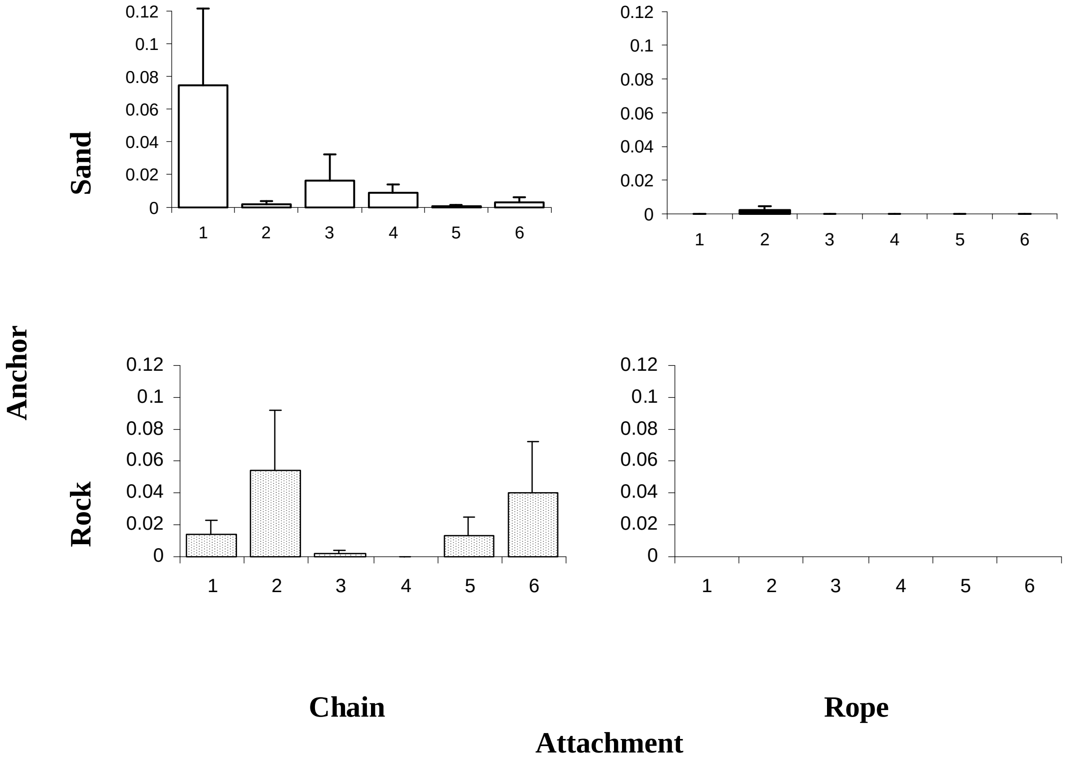


Figure 4.8. Mean (+s.e.) biomass (g dry weight) of *C. taxifolia* fragments removed from Lake Conjola on anchor attachments. Experimental design as in Figure 4.7. Experiments were done in Lake Conjola on 27th May 2003.

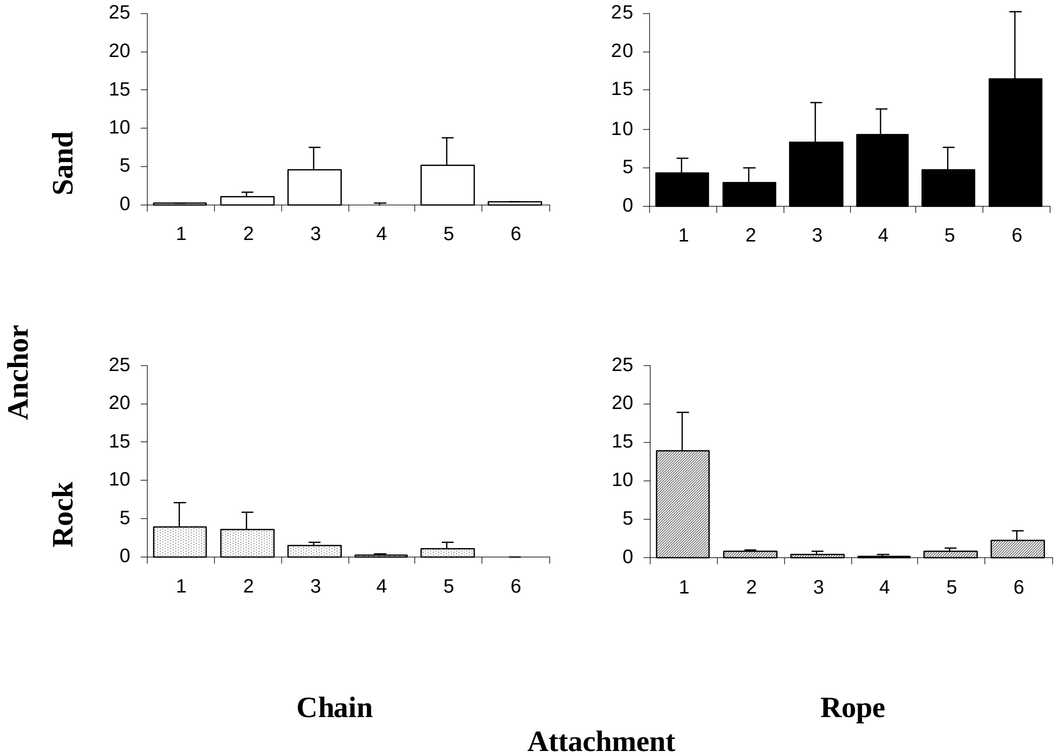


Figure 4.9. Mean (+s.e.) biomass (g dry weight) of *C. taxifolia* fragments removed from Lake Conjola on anchors. Experimental design as in Figure 4.7. Experiments were done in Lake Conjola on 28th July 2003.

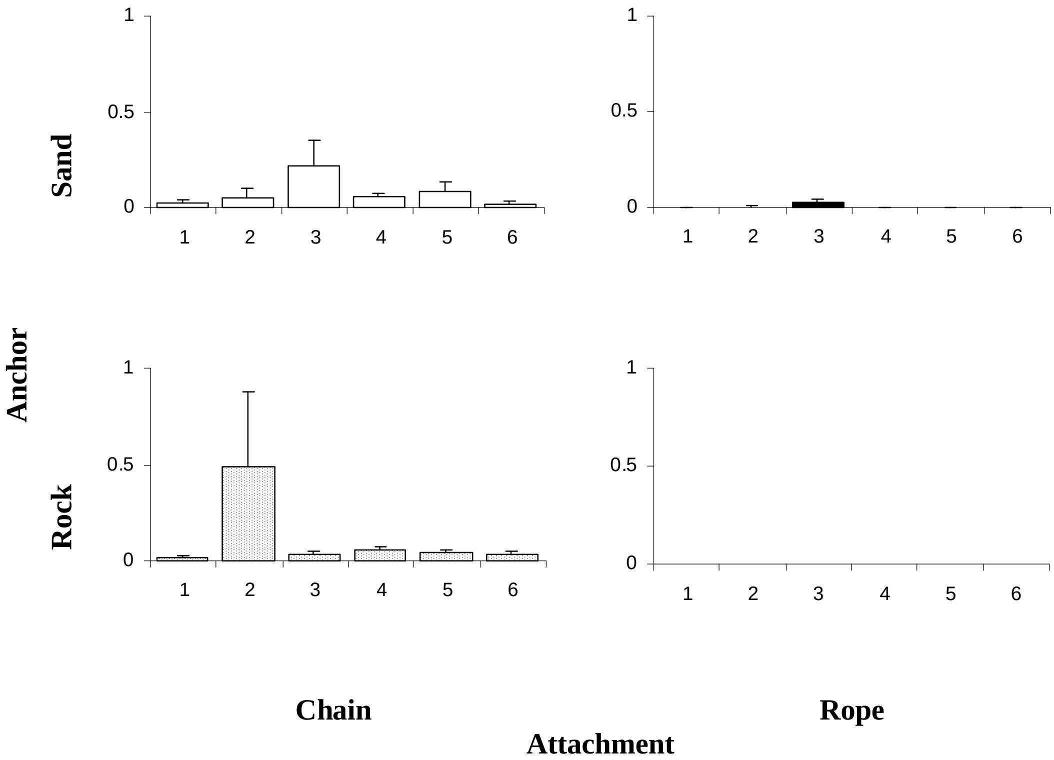


Figure 4.10. Mean (+s.e.) biomass (g dry weight) of *C. taxifolia* fragments removed from Lake Conjola on anchor attachments. Experimental design as in Figure 4.7. Experiments were done in Lake Conjola on 28th July 2003.

Table 4.6. Results of ANOVAs to test for differences in biomass of *C. taxifolia* fragments removed by anchors. Note: F-ratios in bold were calculated after non-significant (P>0.25) interactions were pooled or eliminated to test for main effects. ns not significant; * <0.05; ** <0.01; *** <0.001.

Source	***df***	**Experiment 1**			**Experiment 2**		
		MS	**F**	**F versus**	**MS**	**F**	**F versus**
Anchor	1	0.95	**0.49** ^{ns}	**R(An)**	4.09	**0.01** ^{ns}	**R(An)**
Replicate Anchor (An)	4	1.94	5.95*	R(At)xR(An)	0.87	0.43 ^{ns}	R(At)xR(An)
Attachment	1	3.74	**3.70** ^{ns}	**AtXR(An)**	12.25	**9.28** ^{ns}	**R(At)**
Replicate attachment (At)	2	0.85	2.62 ^{ns}	R(At)xR(An)	1.13	0.56 ^{ns}	R(At)xR(An)
An x At	1	0.17	**0.16** ^{ns}	**At x R(An)**	5.27	**0.38** ^{ns}	**AnxR(At)**
An x R(At)	2	0.75	2.30 ^{ns}	R(At)xR(An)	3.43	1.72 ^{ns}	R(At)xR(An)
At x R(An)	4	1.01	3.10 ^{ns}	R(At)xR(An)	1.97	0.98 ^{ns}	R(At)xR(An)
R(At) x R(An)	8	0.33	0.49 ^{ns}	Res	2.00	1.67 ^{ns}	Res
Residual	120	0.66			0.75		
Total	143						
Transformation			Ln (X+1)			Ln (X+1)	
Cochran's			*			ns	

Table 4.7. Results of ANOVAs to test for differences in biomass of *C. taxifolia* removed from Lake Conjola by the attachments, chain or rope, of anchors. Note: F-ratios in bold were calculated after non-significant (P>0.25) interactions were pooled or eliminated to test for main effects. ns not significant; * <0.05; ** <0.01; *** <0.001

Source	df	Experiment 1			Experiment 2		
		MS	F	F versus	MS	F	F versus
Anchor	1	0.000	0.07 ns	R(An)	0.000	0.38 ns	R(An)
Replicate Anchor (An)	4	0.002	0.88 ns	R(At)xR(An)	0.013	0.65 ns	R(At)xR(An)
Attachment	1	0.011	6.41*	R(At)	0.142	9.28 *	R(At)
Replicate attachment (At)	2	0.002	0.36 ns	R(At)xR(An)	0.015	0.79 ns	R(At)xR(An)
An x At	1	0.000	0.13 ns	AnxR(At)	0.000	0.38 ns	R(An)
An x R(At)	2	0.001	0.45 ns	R(At)xR(An)	0.001	0.04 ns	R(At)xR(An)
At x RA(An)	4	0.002	0.94 ns	R(At)xR(An)	0.011	0.56 ns	R(At)xR(An)
R(At) x RA(An)	8	0.002	1.58 ns	Res	0.020	1.25 ns	Res
Residual	120	0.001			0.009		
Total	143						
Transformation			Ln(X+1)			Ln(X+1)	
Cochran's			**			**	
SNK							
Attachment			Chain>Rope			Chain>Rope	

4.4. The ability of *C. taxifolia* to survive exposure to air

Experiments in the Mediterranean have indicated that *C. taxifolia* could survive for many days once removed from the water (Sant *et al.* 1996). The so called 'boat transportation hypothesis' is consistent with the appearance of new infestations at sites quite some distant from established populations. Here, the role that boats may play in transporting *C. taxifolia* once removed from the water was assessed under conditions prevailing in NSW. Exposure to air is thought to be the main factor affecting the viability of fragments once onboard a vessel. It has also been suggested that *C. taxifolia* may avoid desiccation if covered by wet rope, attached to wet fishing gear, or placed in shaded areas, such as in anchor boxes or in the bow of a boat. It is also possible that the size of clumps of *C. taxifolia* may influence viability under desiccating conditions. An experiment was designed to examine the survival of *C. taxifolia*, out of water, under a variety of conditions and for several periods of time.

4.4.1. Method

C. taxifolia was collected from Lake Conjola in October, 2003, transported to the laboratory and divided into clumps of three sizes. Each clump of *C. taxifolia* was placed in a 30 cm x 15 cm aluminium tray randomly positioned in one of four large fibreglass containers (1 m x 2 m). The fibreglass containers were positioned in direct sunlight. To test if wet rope prolonged the survivorship of *C. taxifolia,* small piles of rope, previously soaked in seawater, were placed on half of the fragments in each large container. To test the effects of shade, two of the containers were completely covered with a piece of wood, placed 50 cm over the trays (to allow airflow). The shading treatment was designed to simulate anchor box conditions at the bow of a boat. Consequently, 3 factors were investigated; period of desiccation, presence/absence of wet rope, and shade vs exposure to direct sunlight.

Two replicate fragments from each combination of factors were collected after each of 3 periods of time; 1 hour; 1 day; and 3 days of desiccation. Once collected, they were placed into re-circulating seawater aquaria and their viability was determined. Fragments were recorded as being viable if they had any green colouration after one week in the aquaria; non viable fragments were colourless and either limp or in the process of disintegrating. The desiccation time intervals were chosen to represent realistic periods that *C. taxifolia* may be kept out of water during normal boating activities. For example, 1 hour may represent the period of time an angler takes to move between fishing locations within an estuary. One to three days may represent the period of time it takes for a boat to be transported between estuaries.

4.4.2. Results

All large clumps of *C. taxifolia,* and some medium and small clumps, were viable after one hour out of water under all experimental conditions (Table 4.8). Some medium and large clumps of *C. taxifolia* remained viable after the 1 day period of desiccation, but all clumps, regardless of size or treatment, were dead after the 3 day period of desiccation (Table 4.8). These preliminary data indicate that *C. taxifolia* fragments that are lodged in anchor wells or on fishing gears may survive short periods of desiccation which would allow them to be transported to new sites within an estuary or to new sites in nearby estuaries.

Table 4.8. Number of small, medium and large clumps of fragments that were viable after 1 hour, 1 day and 3 days of desiccation under experimental conditions. Note that each treatment combination initially had four viable clumps of fragments.

Clump size			**Small**	**Medium**	**Large**
1 Hour	**Sun**	**Rope**	2	4	4
		No Rope	1	2	4
	Shade	**Rope**	3	4	4
		No Rope	1	3	4
1 Day	**Sun**	**Rope**	0	1	1
		No Rope	0	0	0
	Shade	**Rope**	0	1	3
		No Rope	0	1	1
3 Days	**Sun**	**Rope**	0	0	0
		No Rope	0	0	0
	Shade	**Rope**	0	0	0
		No Rope	0	0	0

4.5. Public awareness of boating activity as a potential vector – a preliminary study

A questionnaire was designed by a student at Wollongong University to examine the types of boating activity done in the south coast lakes of NSW and to identify if members of the boating public had observed the alga. This questionnaire was trailed in a preliminary survey in March 2003. The responses from this preliminary survey (see Appendix 3) were used to design a more comprehensive questionnaire that could be used to further quantify recreational vectors that might potentially transfer *C. taxifolia* to new locations (Appendix 3).

It is recommended that managers adopt this revised questionnaire to gain a broader understanding of community knowledge and potential vectors. It is important that a broad range of people who use the south coast lakes for recreational activities is sampled to allow as many transport vectors as possible to be identified. In order to do this, a suggested sampling protocol would be a combination of face-to-face surveys and questionnaires placed in local shops and businesses. Face-to-face sampling would best be done at weekends or during school holiday periods in summer (i.e. at Christmas and Easter). Questionnaires could be placed in local shops and businesses, such as the local takeaway and bottle shop at Conjola or on the Port Hacking Ferry Service and marina in Port Hacking. This would involve the production of leaflets to explain what *C. taxifolia* is and why people should fill out the questionnaire. A box or other collection point could be provided, perhaps in co-operation with the local business owners, in which people could place their completed surveys.

4.6. Discussion

The monitoring undertaken in Port Hacking and Lake Conjola has confirmed that a variety of anthropogenic activities are capable of generating fragments of *C. taxifolia*. Large quantities of unattached fragments were observed year round in the vicinity of infestations (section 3.1.1). These fragments were significantly more abundant in locations with high levels of anthropogenic activity, particularly where boats were operating in the vicinity. The results from the experiments strongly suggest that boats are an important mechanism for creating fragments as they move over established beds of *C. taxifolia*, particularly in shallow water. Here, dramatic increases in the presence of fragments was found. Although this is of concern in the shallow estuarine locations in which *C. taxifolia* has established, the addition of fragments to well established beds which are not exposed to strong water movement does not appear to significantly increase the biomass of the invader (Wright and Davis, in prep.). As this work was done under the auspices of an ARC Postdoctoral Fellowship it will be reported elsewhere.

The anchoring of vessels also has the potential to create fragments and move these fragments onto vessels for translocation within and between estuaries. Sand and rock anchors will both remove significant quantities of fragments, although rope when used as a means of attaching anchors had little impact on removing *C. taxifolia* from the water. Importantly, anchor chain removes fragments and, as these fragments are relatively small, they are likely to be missed by boaters and not removed from the anchor gear. These small fragments attached to chain have the potential to be translocated to other locations within estuaries, but are unlikely to remain viable for translocation to other estuaries. It is clear from the desiccation experiments that only relatively large clumps of *C. taxifolia*, particularly those that are shaded and covered with damp anchor warp, are likely to survive translocation between estuaries. The survival times recorded in our experiments are much less than those reported from a similar study in the Mediterranean where *C. taxifolia* fragments could apparently survive for one week when kept emerged in dark and humid conditions (Sant *et al.* 1996).

Our findings are generally supported by overseas studies that also suggest that anchors and anchor chains have been important in creating and translocating fragments of *C. taxifolia* (Meinesz *et al.* 1993; Boudouresque 1996). Taken together, these findings support the practice, already adopted in many infested areas, of using educational signage to alert the public to the possibility that fragments may be attached to their boating equipment and that they may be inadvertently assisting in the spread of *C. taxifolia* to new locations. It is recommended that additional information about the general public's awareness of these risks should be obtained, perhaps by the use of questionnaires used in conjunction with other advisory material (as outlined in the NSW control plan; http://www.fisheries.nsw.gov.au/thr/species/fn-caulerpa.htm). The results of our research also support the practice of establishing 'no-anchoring' zones in infested areas. These exclusion zones should prevent anchors from generating new fragments and, more importantly, should prevent their translocation to other locations. Where *C. taxifolia* grows in very shallow water at, or adjacent to, public boat ramps or other boat launching areas, propellers, oars or the boat hulls themselves may damage *C. taxifolia* plants and release fragments. Rather than also excluding boating activity from these sites, treatment of the seaweed is recommended (as described in Chapter 5).