ARTICLES

Effects of Logging on the Marine Environment at Onepua Bay, Marlborough Sounds

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ABSTRACT

Changes in coastal seabed habitat and sediments monitored from 1992 to 1995 were not caused by logging activities during that period. Significant differences ($P<0.05$) in proportions of fine sediments, and the numbers and types of marine life were attributed to natural variation and/or storm-induced sedimentation rather than logging activities. The flushing effect of wave and tidal action was a major factor preventing the accumulation of fine sediments, and associated biological impacts, on the near-shore seabed below the logged area. While it was not possible to separate logging versus storm effects, we cannot rule out long-term effects as more of the catchment is logged.

CONCERNS ABOUT FORESTRY IMPACTS

In 1981, Johnston, Mace and Laffan wrote about the concerns of increased soil erosion resulting in deposition of fine-grained sediments and tree detrius in the Marlborough Sounds (Figure 1). They indicated that this would decrease the existing high water quality in the sounds and threaten marine life and farming, fishing, and the aesthetic qualities of the Sounds. Logging of Farnham Forest (Snake Point) in Queen Charlotte Sound from 1970-1981 was used to illustrate the concerns of Johnstons et al.

SEDIMENTS IN THE SOUNDS

At Farnham Forest, O'Loughlin (1979) found that erosion of a skidder track crossing a stream resulted in average suspended sediment concentrations of 13000 ppm at the mouth of the stream compared to 30 ppm from an unlogged catchment. However, sediment concentrations declined to 21-30 ppm 50m from the shore. Nearshore discoloured seawater cleared in less than 24 hours.

In general, water quality declines towards inland areas of the Marlborough Sounds. According to mussel farmers, mussels grow faster and are in better condition in areas of low turbidity (Wilks, 1980). During fine weather conditions, suspended solid concentrations range between 0-10 ppm (O'Loughlin, 1980). Natural suspended sediment levels in the Sounds' waters will only rarely approach 100 ppm — for a short time — and this is near the tolerance limit for mussels (Wilks, 1980).

The concentration and distribution of suspended sediment varies greatly throughout the Sounds (Wilks, 1980). This is reflected in the variation across the region in rainfall intensity, water depth, tidal patterns, salinity, nature of the surrounding landform, proximity to major river outflows, and distance offshore. For example, Pelorus Sound is naturally silty with high turbidity for 20 km, during floods from the Pelorus River. Ebb tides exceed flood tides in the Sounds and play an important role in determining the direction of sediment transport (Heath, 1981).

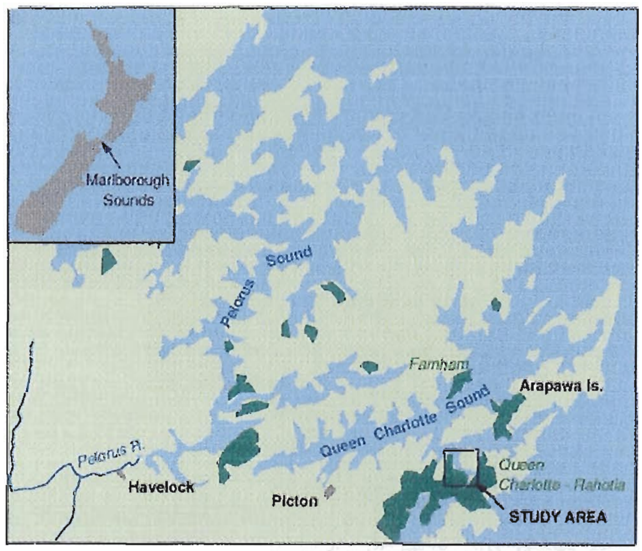

Figure 1. Plantation forests in the Marlborough Sounds.

Johnston et al. (1981) study of the seabed surrounding Farnham Forest suggested that logging contributed up to 20 mm of fine sediment in sheltered bays relative to unlogged bays.

At the head of Opua Bay (sic, Onepua Bay, Figure 2), an estimated 5-10 mm/yr of seabed sedimentation has occurred since indigenous forest clearance approximately 100 years ago (Coker and Fahey, 1992). Natural sedimentation was mainly attributed to shoreline erosion of the clay-rich soils in the area. This occurred in response to the rise in sea-level and tectonic uplift over the last 6000 years. During this time about 6-8 m of sediment has been deposited on the seabed (Lauder, 1987; in Coker and Fahey, 1992).

Fahey and Coker (1992) estimated that 62 t/km2/year of sediment was being removed by surface erosion of forest roads, tracks and firebreaks in Queen Charlotte Forest. However, background rates of erosion were estimated at 300-600 t/km2/year. Up to 200 t/year of fine sediment could enter the headwaters of Onepua Bay (Fahey and Coker, 1992).

LOGGING AT ONEPUA BAY

In early 1991, the Forestry Corporation of New Zealand Limited initiated harvesting plans to log 138 ha of Rahotia Forest at Onepua Bay (Figure 2). Planted in 1969, the stand of radiata pine was logged at age 22 to 24 years. Approximately 80,000 tonnes were to be logged and transported over 24 years.

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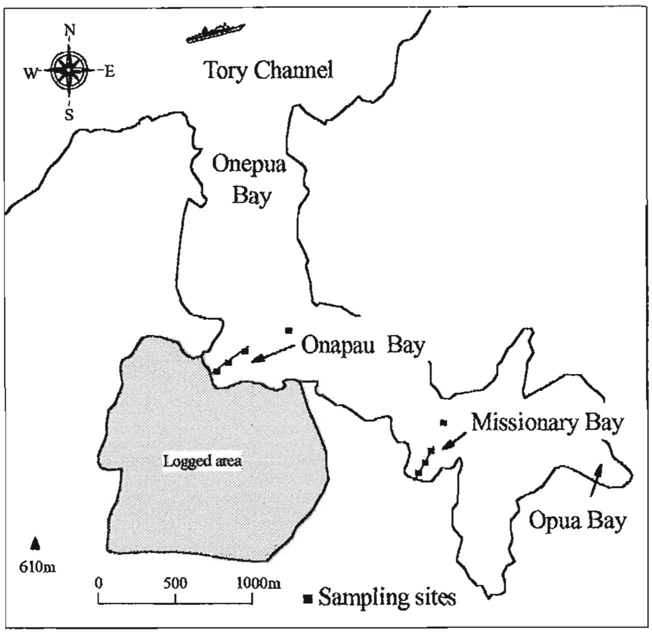

Figure 2. Detail of study area and sampling sites.

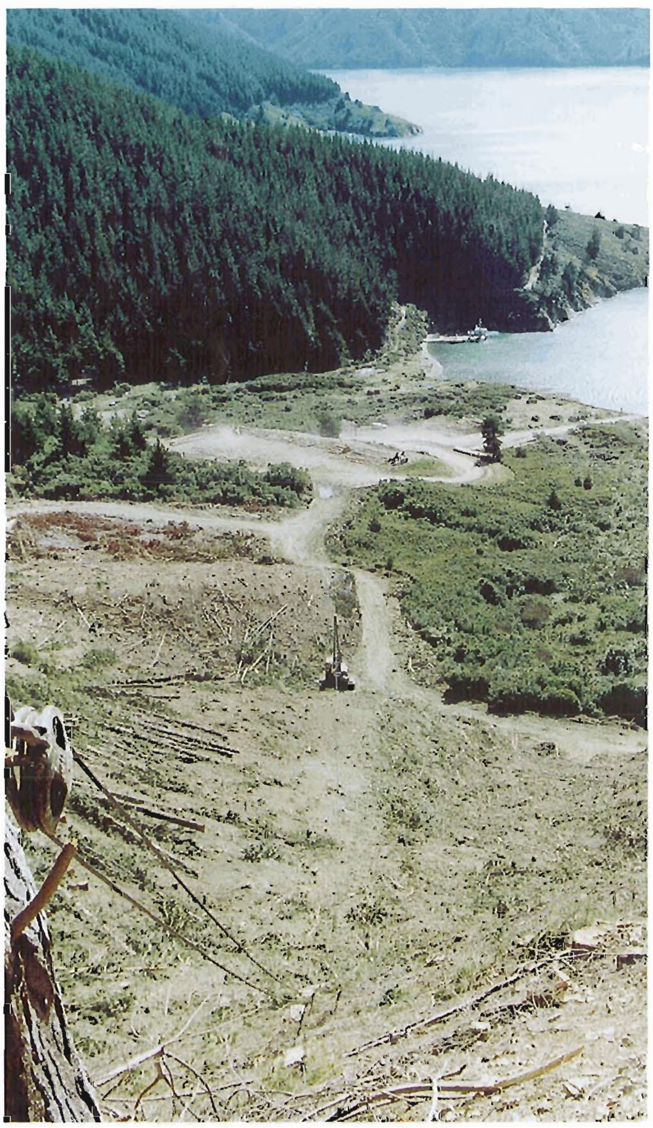

Figure 3. Harvesting operations at Onapau Bay in 1992.

The primary concern at Onepua Bay was to minimise erosion from road, track and landing operations in this very steep terrain (Spiers, 1992). Slopes in the harvesting area average 300 and rise to a maximum 611 m above sea level (a.s.l.). The silt and clay soils, particularly below 200 m a.s.l. where the schist bedrock is strongly weathered, were considered an important source of fine sediment during runoff (Coker et al., 1993). Harvesting conditions would be difficult due to poor road access and proximity to the Arapawa Island power supply (Coker and Fahey, 1992). One option was to build a new road. However, barging logs 19 km to Picton was preferred, which avoided high roading costs and the potential erosion risks (McConchie, 1992, Robinson, 1993; Coker et al., 1993).

Initially a two-stage system was employed to extract trees downslope to a processing deck sited near the shore (Figure 3). A swing-yarder was used to extract tree lengths to a midslope track, followed by skidder extraction to one of a number of small processing decks (Figure 4) (Robinson 1993). Stems were then yarded distances of up to 650m by either single, or multispan standing skylines, to a lower deck and barging point (McConchie and Robinson, 1996).

Re-establishment occurred naturally through re-generation of radiata seedlings. Colonisation by gorse was also widespread.

MARINE IMPACT SURVEYS

Liro Limited initiated a marine impact study to test whether the logging operations at Onepua Bay would: 1) result in an increase in sea-floor sediment levels and, 2) lead to significant changes in marine habitat and the biological community structure. Mussel farms are not present in Onepua Bay.

Four surveys were performed by the Cawthron Institute, Nelson in: February 1992 (coinciding with the start of logging), March/April 1993, February 1994, and April 1995 (six months after logging was completed).

Two small bays within Onepua Bay were studied; (1) Onapau Bay and (2) Missionary Bay (Figure 2). At Onapau Bay, approximately 140 ha of a 290 ha catchment was logged during the study. Missionary Bay was fringed by a 110 ha forested catchment which remained unlogged for the entire period. Within each bay, three sampling sites were established along transects that extended from the shoreline to 210 m offshore (Figure 2). These transects and sampling sites were used for all surveys. Extra sites were surveyed in central Onepua Bay in 1994 and 1995, along the line of the transects.

SCUBA and intertidal surveys recorded the condition of the sea-bed and substrate type along with prominent biological associations. Four to five core-tube samples were collected at each site; 62 mm diameter for sediment grain size analysis, and 131 mm diameter for fauna analysis. In the laboratory, the upper 2 cm layer of the smaller core was split off to determine the percentage weight of sand, silt and clay. A list of the taxa and the abundance of each was derived by washing the top 150 mm of each of the fauna cores through a 0.5 mm sieve and examining the retained biota under a microscope. Water samples were analysed for colour, suspended solids, and tannin like substances. Dissolved oxygen concentrations were measured in the field with a meter and submersible probe.

CHARACTERISTICS OF THE NEAR SHORE ENVIRONMENT

Both bays have gently sloping cobble/shingle beaches which extend 20 m from the mean high water spring line. In the subtidal zone the off-shore slope is steeper and comprises mainly gravel and shells. Onapau Bay has a more gradual rock and boulder slope in contrast to Missionary Bay (non-logged).

The coastal fringes were bordered by low-lying scrub and regenerating bush. Sea rush fringed the upper intertidal zone where driftwood and debris were abundant. In the intertidal and shallow subtidal regions to a distance of about 25 m offshore from the high water mark, both transects were relatively free of surface silt to about 4 m depth. This probably reflects wind and wave activity preventing sediment accumulation there. Beyond 30 m the seabed was dusted with fine sediments which thickened seaward.

Relatively little pine debris was noted at Onapau Bay and Missionary Bay prior to logging. Pine debris was generally littered from 65-105 m offshore at 10-12 m depth.

The biological community structure of the sea floor reflects the type of substrate (gravel, sand and mud) and the amount of past erosional sediment input. The shallowest sites had the most diverse communities and the largest number of individual organisms. The community structure was consistent with other parts of the Marlborough Sounds with reduced numbers of taxa associated with finer textured, deeper sediments.

The transect samples comprised mainly sand with mean values at Onapau Bay from 59 to 83% and at Missionary Bay from 50 to 72%. Clay contents were relatively uniform (5 to 9%), but the silt contents varied considerably (14 to 41%). The results showed that silt contents were highest 210 m from the shoreline at 13 to 15 m depth, and higher overall at Missionary Bay than at Onapau Bay.

As Missionary Bay is located further from Tory channel, wave action and tidal current energy are likely to be less than at Onapau Bay. Therefore differences in the proportion of fine sediment between the two bays probably reflect differences in near-shore sediment flushing (McMahon et al., 1996).

Sediment organic contents were low (1.9-4.9%) and were typical of other bays in the Tory Channel region (Cawthorn Institute unpublished data). This was consistent with sediment profile observations that indicate no significant oxygen depletion. Measured dissolved oxygen levels gradually declined from 8.0 mg/l at 1 m depth to 7.3 mg/l at the seabed at both outer sites during the 1992 survey.

Suspended solid concentration of seawater and streams were sampled at only one time. Stream inflows were low, with suspended solids of 7.4 and 4.6 ppm for the two streams at Onapau Bay, and 22 ppm at Missionary Bay. At the outer sites, suspended solid levels of seawater were similar (13 & 15 ppm) but were slightly less at 10m depth (12 & 9 ppm). The results compare favourably with those of O'Loughlin (1979, 1980).

RAINFALL

Rainfall data was obtained at Port Underwood (National Institute of Water and Atmosphere - Site 142036) eight kilometres southwest of Onepua Bay. The daily rainfall data (Figure 5) was only indicative of that occurring at Onepua Bay, due to the large rainfall variations that can occur across the Sounds (Phillips et al., 1996).

Significant rainfall events occurred during February 1993 (74 mm in 24 hours) and May 1993 (69 mm in 24 hours). In November 1994 just after completion of logging, a major storm event caused effects which were observed during the 1995 survey. A total 241 mm of rain fell from 5-8 November, with a maximum daily rainfall of 135 mm. Following this storm and prior to the 1995 survey, the maximum daily rainfall did not exceed 45 mm.

The November storm event resulted in numerous slips along the nearby shoreline regions of Tory channel and Queen Charlotte Sound. Erosional effects were visible in shoreline regions of Onapau and Missionary Bays.

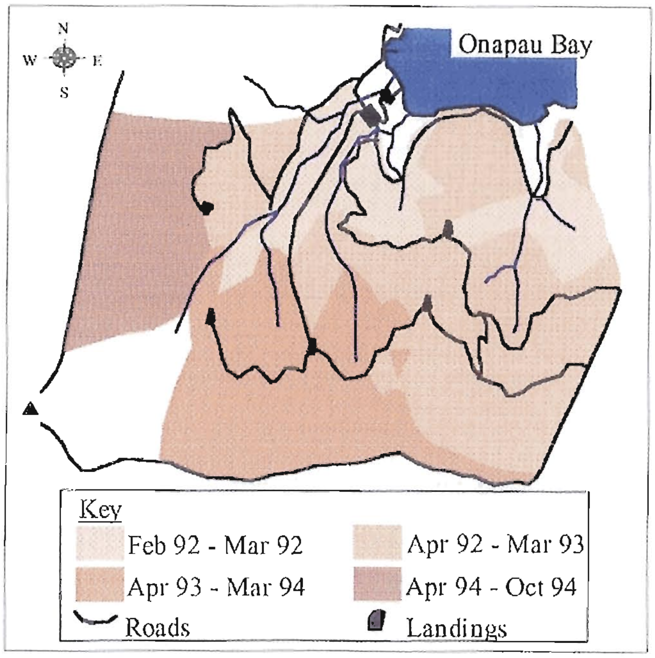

Figure 4. Logging pattern at Onapau Bay from February 1992 to October 1994.

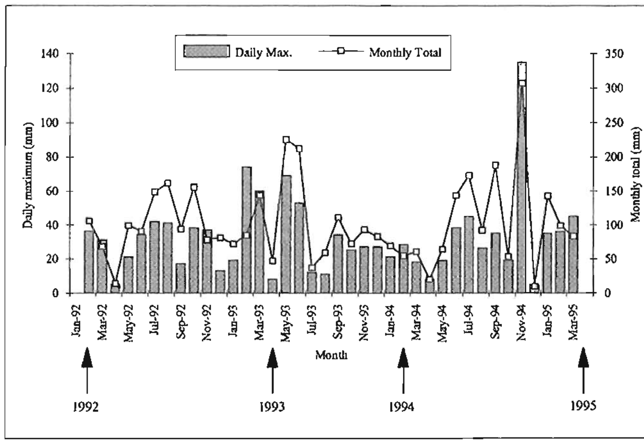

Figure 5. Maximum daily rainfall each month, and monthly total rainfall for the period of the study. The timing of the marine surveys is shown.

CHANGES DURING LOGGING

Sea-bed Sediments

At the time of the 1995 survey, some localised effects of the November storm were evident. A small delta had formed at the mouth of the two streams at the logged site (Gillespie and Asher, 1995). On the shore, patches of soft gravel and silt were observed amongst the hard cobbles. Loose deposits of sediment were limited to a small area at the base of the stream delta. Near the central processing area, where the stream had been diverted, storm flows had re-routed the stream back to its original course (Phillips et al., 1996). This then would have been the primary source of sediment to the shore. The smaller eastern stream drained an area of cutover where a landslide had occurred during the November 1994 storm (Phillips et al., 1996). No landslide debris had entered the bay. At the time of the 1995 survey, the delta appeared to be returning to a clean gravelly state through the gradual winnowing of fine sediment by tides and waves.

From 1992-1995 the intertidal and subtidal seabed remained free of fine sediment to a distance of 25 m at Onapau Bay. During the 1995 survey, deposition of fine sediment was noted at the base of the rock slope (35-45m from the high water mark) with patches of silt up to 1 cm thick from 50-120 m offshore. There was shoreward spread of the deep bottom mud habitat by a few metres.

Significant changes in the mean proportion of fine sediment occurred over time along the Onapau Bay transect (Table 1). Annual variations in fine sediment was statistically tested by Least Significant Difference pairwise comparisons of means using a 95% level of confidence. At 40 m offshore, a significant increase in the proportion of fine sediment occurred during the second year (1994 sampling); but in the third year, silt and clay content decreased significantly from 31% to 13% (which was similar to the 1992 observation). At 90 m offshore, silt and clay decreased from 20% to 7% over the three-year period. There were no significant changes in the deeper offshore sediments.

During the period of logging activities there was no pervasive increase in the proportion of fine sediments on the sea floor. The observed changes were attributed to natural influences. These results contrast with the logging at Farnham Forest where increased erosion caused deposition of fine sediments in near-shore regions (Johnston et al. 1981).

The control bay was more severely affected by the November 1994 storm. Debris from a slip in the forested catchment and stream channel erosion resulted in the formation of a large delta in the vicinity of the stream mouth (McMahon et al., 1996; Figure 6). Soft shingle and silt covered the pre-existing beach and continued down the offshore slope. The increase in fine sediments appeared to gradually decline to a thin dusting of silt from 40 m to 60 m along the transect (Gillespie and Asher 1995).

Despite major changes in shoreline sea-bed topography, the proportions of fine sediments remained relatively uniform over three years at Missionary Bay (Table 1). The mean proportion of fine sediment at 70 m had significantly increased in 1995 compared to 1994; but was not significantly different to 1992.

Pine debris was thinly scattered throughout the subtidal zone during the survey period. A more heavily littered band about 20 m wide was noted off Onapau Bay in 1993. In the 1995 survey, woody pine and lesser amounts of native vegetation was more widespread, but more thinly scattered than in previous years. Sediment analyses showed that concentrations of total organic and tannin-like substances at all sampling sites were within ranges expected for the region (Gillespie and Asher, 1995). The results suggest that any increased sediment and/or organic input from the logged area were dispersed rapidly over the greater Onepua Bay and consequently associated impacts were minimal.

Marine Life

Sea floor animals and plants along the Onapau Bay transect were similar in successive surveys. Any changes which may have been caused by the November 1994 storm were no longer evident six months later. Therefore, it can not be ascertained if the marine life was adversely affected during the storm.

The apparent stability at Onapau Bay was in contrast to that at the Missionary Bay transect where there was considerable change to the physical and biological habitat of the intertidal and shallow sub-tidal environment (Figure 6). Storm-induced delta formation either washed away or buried near-shore encrusting communities. Mobile animals may have also been displaced by storm-induced disturbances, but had re-colonised by the 1995 survey. Plant and animal associations away from the stream mouth remained much the same as in previous years.

Further offshore a slightly different result was in the analyses of the species richness (number of different taxa) and abundance of individual fauna within the two bays (Table 2). Over the period of the four surveys, no clear patterns of change in species richness were discernible in either bay. Since species richness is a good indicator of environmental stability, it was reasonable to assume that any observed changes, as at April 1995, were related to sea-bed disturbances (Gillespie and Asher, 1995).

Of the observed changes over the monitoring period, there was a significant decrease in the mean number of taxa 40 m offshore at Onapau Bay, but taxa numbers were not significantly affected by the November 1994 storm. In contrast, a significant reduction in the average number of taxa occurred 90 m offshore

Figure 6. Stream delta in Missionary Bay showing fine sediment and debris deposited after the November 1994 storm.

ONAPAU BAY TRANSECT SITES - LOGGED						
Distance (m) from shore	**Depth (m)**	**Sediment Type**	**Mean % Silt and Clay**			
			1992	**1993**	**1994**	**1995**
40	5 - 6	Patchy sand/gravel/shell	19_a	12_b	31_c	13_b
90	10 - 11	Muddy sand/mud	20_a	18_{ab}	15_b	7_c
210	13 - 14	Soft mud	41_a	45_{bc}	43_{ab}	46_c
550	15	Soft mud	-	-	35_a	38_b
MISSIONARY BAY TRANSECT SITES - UNLOGGED						
70	8 - 10	Mud/sand/gravel/ shell	33_a	37_{ab}	35_a	42_b
125	9 - 10	Mud/sand/gravel/ shell	32_a	38_b	35_{ab}	40_b
210	13 - 14	Soft mud/sand	50_a	43_b	41_b	46_{ab}
350	16 - 17	Soft mud	-	-	52_a	38_b

Table 1. At-a-site pairwise comparison of yearly mean percentage of fine sediments found in top 2 cm of replicated cores. Means that are not significantly different (P<0.05) have matching letter subscripts, whereas means that are significantly different have non-matching letters.

ONAPAU BAY TRANSECT SITES - LOGGED								
Distance (m)	**Mean Number of Taxa**				**Mean Number of Individuals**			
	1992	**1993**	**1994**	**1995**	**1992**	**1993**	**1994**	**1995**
40	38_a	33_{ab}	33_{ab}	27_b	463_a	425_a	172_b	124_b
90	19_a	23_{ab}	25_b	14_c	148_{ac}	208_{ab}	252_b	71_c
210	17_a	15a	19_a	15_a	58_{ab}	49_b	79_a	40_b
550	-	-	19_a	15_a	-	-	74_a	31_b
MISSIONARY BAY TRANSECT SITES - UNLOGGED								
	1992	**1993**	**1994**	**1995**	**1992**	**1993**	**1994**	**1995**
70	24_a	28_{ab}	33_b	27_a	134_a	210_a	179_a	139_a
125	21_a	23_{ab}	27_b	19_a	199_a	181_a	176_{ab}	99_b
210	14_a	21_b	26_c	22_b	87_a	157_b	131_{ab}	103_a
350	-	-	15_a	21_a	-	-	42_a	87_b

Table 2. At-a-site pairwise comparison of yearly mean percentage of number of taxa and individuals found in top 2 cm of replicated cores. Means that are not significantly different (P<0.05) have matching letter subscripts, whereas means that are significantly different have non-matching letters.

in 1995 (Table 2). In the deeper soft offshore muds the mean number of taxa did not change significantly.

Significant decreases in the mean number of individuals per core (another potential indicator of disturbance) were also observed at a number of sites in the 1995 survey (Gillespie and Asher, 1995). At 40 m offshore from the logged catchment of Onapau Bay, the average number of individuals gradually declined over time, with the only significant difference occurring between 1992 and 1993 surveys. At 90 m offshore significant reductions occurred in 1995 compared to 1994, but not compared to 1992 (Table 2). However, at Missionary Bay, a gradual reduction in mean number of individuals occurred 125 m offshore during the entire monitoring period. No clear distinction can be made between sites adjacent to the logged versus the unlogged sub-catchments. Furthermore, reductions in community abundance did not correspond with an increase in fine sediments on the seabed. Significant changes in fine sediment and/or marine life within both bays, prior to the November 1994 storm, was attributed to natural fluctuations.

CONCLUSIONS

The effects of logging on the marine environment within Onepua Bay were monitored annually from 1992 to 1995. The marine surveys were conducted below a logged area at Onapau Bay and below an unlogged pine forest at Missionary Bay.

Measurements at two near-shore sampling sites within Onapau Bay showed a significant decrease in fine sediments and benthic animals over the three years. This contrasted with Missionary Bay, which showed significant fine sediment accumulation in the near-shore region.

The lack of observed near-shore fine sedimentation at Onapau Bay and the stronger change in seabed animal associations at Missionary Bay, indicated that factors other than logging, such as natural sediment input and flushing of fine sediments, were responsible for the observed changes over time. Despite the absence of near-shore sedimentation related to logging, it is recognised that accumulation of fine sediments within central Onepua Bay may occur over the longer-term, particularly as more of the catchment is logged.

This study has highlighted the inherent difficulty in establishing the extent to which logging activities affect the near-shore marine environment. Not only do the logged and unlogged sub-catchments need to be similar, but it is also necessary to confirm that near-shore conditions and processes are similar prior to logging.

The study also highlights the difficulty of extrapolating the findings to other coastal sites and the realisation that impacts to the near-shore environment are dependent on site specific hydrodynamic characteristics.

ACKNOWLEDGMENTS

LIRO acknowledges the co-operation and assistance of: Skylok Logging, Picton, the Forestry Corporation of New Zealand the Williams Family, and the Cawthron Institute, Nelson. This study was funded by the Foundation for Research Science and Technology under contract CO4505 - Site Management for Sustainable Forestry.

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