SHORT TERM CHANGES IN FLUSHING OF TIDAL CREEKS FOLLOWING CULVERT REMOVAL

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Abstract

Structures that reduce tidal flushing impact vegetation, fish, invertebrates, and plankton in estuarine wetlands, but many studies have shown that removal or modification of structures leads to at least partial recovery of biological communities. However, few studies have reported the immediate tidal response to structural alterations. Changes in tidal ranges and creek cross-sections following culvert removal from two tidal creeks on Kooragang Island, New South Wales, Australia provide an example for managers interested in altering structures in tidal creeks. Conditions are also reported for two nearby creeks where culverts were left intact. Removal of culverts resulted in increased low-tide drainage at both creeks and dramatically increased current velocity in one creek. These changes may make habitats unsuitable for some fish and invertebrate species, while plant productivity may increase. Changes attributed to culvert removal on Kooragang Island offer some insight regarding management options for over 1,300 structures that impede tidal flow in New South Wales.

Key words: Culverts, estuarine wetlands, rehabilitation, restoration, tidal creeks, tide.

Introduction

The importance of tidal flushing to estuarine wetland productivity is widely recognized (Schelske & Odum 1962, Steever *et al.* 1976, Odum 1980, Odum *et al.* 1995). Structures that reduce tidal flushing cause habitat degradation, affecting vegetation, fish, invertebrates, and plankton (Breen & Hill 1969, Copeland 1974, Weaver & Holloway 1974, Gilmore *et al.* 1982, Rey *et al.* 1991, Harrington and Harrington 1982, Roman *et al.* 1995, Wenner & Beatty 1988). In some cases, removal or modification of structures leads to at least partial reversal of habitat degradation (Rey *et al.* 1990, Sinicrope 1990, Vose & Bell 1994).

Researchers assess the effect of removal and modification of structures by monitoring biological change, but examples of the immediate tidal response to structural alterations are uncommon. Roman *et al.*'s (1995) model, which predicts tidal ranges above floodgates and culverts from local tidal range, Manning coefficients, and size of openings in structures, provides wetland managers with one method of estimating the effect of alterations to structures. However, managers and planners can benefit from examples that illustrate the methods used to alter structures and short-term results of alterations. In July and August 1995, the Kooragang Wetland Rehabilitation Project replaced culverts near the mouths of two tidal creeks with bridges on Kooragang Island, New South Wales, Australia. This paper describes:

1) the replacement of culverts with bridges,
2) the short-term change in tidal ranges following culvert removal, and
3) the short-term change in creek cross-sections resulting from erosion.

Conditions in two creeks where culverts were left intact provide a basis for comparison.

Site and Methods

Kooragang Island is a deltaic feature that divides the north and south arms of the Hunter River (Fig. 1). The city of Newcastle, with a mixture of industry and residential housing, lies to the south. At the mouth of the estuary, the mean tidal range is 1.05 m, and tidal influence extends upstream for about 50 km. The island's 2,560 ha area is divided between an industrial zone in the southeast, a nature reserve in the northeast, and leasehold

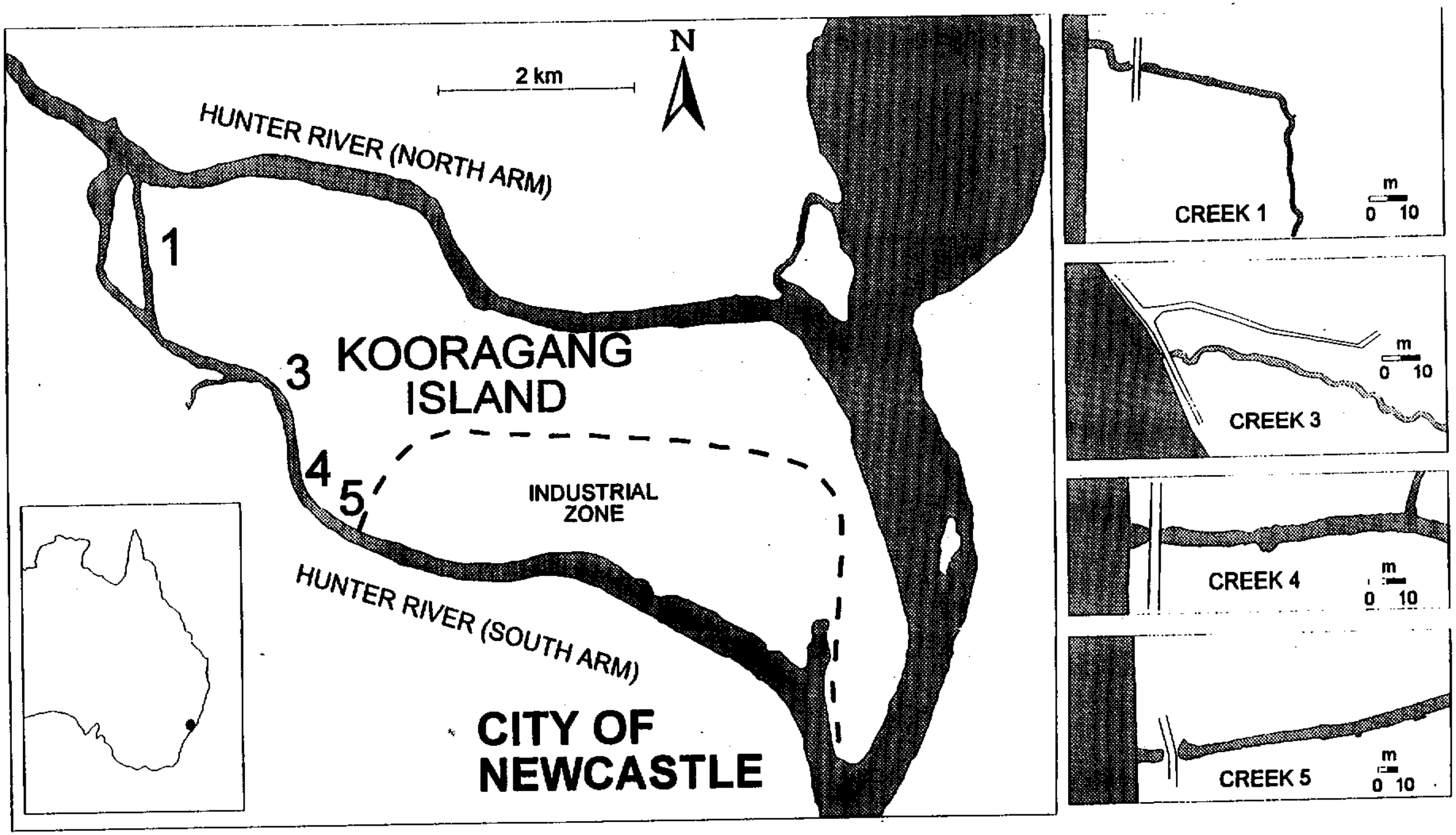

Figure 1. Kooragang Island and the surrounding area, with locations and enlargements of Creeks 1, 3, 4, and 5. The Hunter River and tidal creeks are shaded, while roads are outlined. Culverts were replaces with bridges near the mouths of Creeks 1 and 5.

lands consisting of cattle pasture, saltmarsh, and mangrove in the west. The island's saltmarshes consist of a mixture of samphire (*Sarcocornia quinqueflora*) and salt couch (*Sporobolus virginicus*), with suaeda (*Suaeda australis*) and streaked arrow grass (*Triglochin striata*) as subdominants. Near the upper boundaries of the saltmarsh, the exotic spiny rush (*Juncus acutus*) and the native sea rush (*Juncus kraussii*) occur. Mangrove forests dominated by grey mangrove (*Avicennia marina*) with a shrub layer of river mangrove (*Aegiceras corniculatum*) grow along the lower saltmarsh boundaries and next to tidal creeks (Buckney 1987). Kooragang Island's wetlands support commercially important fish and crustacean species (Williams *et al.* 1995) and at least one hundred and sixty-three bird species have been seen on the island (Coffey 1973).

Immediately after British explorers surveyed the lower Hunter River in 1798, sawyers were landed to harvest upland tree species and mangrove from what is now Kooragang Island (Ord 1988). By 1809 convict labourers were producing mortar by burning oyster shells, leading to a dramatic reduction in the availability of both shells and wood within six years (Thompson 1815). Wetlands were further impacted by farming and subsequent alterations to drainage patterns from the early 1800s onward. In 1953, the Newcastle Harbour Improvements Act called for conversion of the lower Hunter River islands to a "single land mass" that would be called Kooragang Island (Moss 1983). By 1972, attitudes towards environmental protection had changed, and the State Pollution Control Commission recommended that "a fairly large part of the presently undisturbed area of the Island should be preserved in its natural state" (Coffey 1973). Support for preservation of existing wetlands evolved into support for rehabilitation of degraded wetlands on the western end of Kooragang Island. In 1992 the Kooragang Wetland Rehabilitation Project was founded to rehabilitate, restore and create fisheries and other wildlife habitat on the western end of Kooragang Island, where the dominant land use is cattle grazing (Shortland Wetlands Centre Ltd. 1992).

Five tidal creeks connect wetlands of the island's western end to the Hunter River. Concrete culverts of various diameters near the mouths of Creeks 1, 3, 4, and 5 restricted tidal flow until mid-1995 (Table 1). Creek 2, where a culvert collapsed in April 1990 (Genders 1996), is not considered in this study. In July and early August 1995, culverts at Creeks 1 and 5 were replaced by bridges designed to eliminate the restriction of flow. Bridge construction required:

1) installation of temporary dams to restrict tidal flow while work was in progress,
2) excavation of culverts,
3) installation of footings on both sides of the creeks,
4) bolting a double layer of 30-cm diameter wooden power poles across the creeks,
5) placement of a double-layer of geofabric on top of wooden power poles,
6) covering the geofabric with 30 cm of roter mill road base, and
7) removal of temporary dams to reestablish tidal flow.

Works were completed in 16 and 17 days at Creeks 1 and 5, respectively. Bridges span 7 m. The bridge across Creek 1 cost A$21,990 while the bridge across Creek 5 cost A$24,660. Bridges are expected to last over 20 years. Culverts at Creeks 3 and 4 were left intact to provide control data for ongoing comparisons of fish, bird, and plant communities between altered and unaltered creeks.

To assess immediate changes in tidal ranges within creeks, water levels were measured above and below culverts at 15-minute intervals during daylight hours on 2 days before culvert removal (25 May and 6 June 1995) and on 2 days after culvert removal (15 August and 3 October 1995). Measurements were taken from staff gauges installed below culverts near creek mouths and 50-90 m above culverts in creek channels. All measurements were referenced to the culvert invert, so that the 0-cm mark matched the bottom edge of culvert openings, which is the point where rising tides begin to inundate creeks and falling tides cease to drain creeks. Because tidal ranges change from day to day and may be influenced in an unpredictable manner by wind and river flow, we used measurements from the two unaltered creeks to provide information on changes unrelated to culvert removal. In addition, we measured short-term erosion by surveying cross-sections of Creeks 1 and 5 before (27 and 29 June 1995, respectively) and after (5 and 3 October 1995, respectively) culvert removal. Surveys of cross-sections on two dates for Creeks 3 (10 August and 5 October 1995) and 4 (10 August and 3 October 1995) provided information on background change unrelated to culvert removal. At each creek, cross-sections were measured at two locations (Table 1).

channel empty with the exception of pools within the channel. Following culvert removal, the rising tide above the bridge was not as severely restricted as it had been by the culverts, as seen by comparing 25 May and 3 October tides. Fish assemblages within the creek may change in response to the loss of permanently flooded habitat, but culvert removal allows for more thorough flushing by higher tides and may result in increased productivity.

			Distance from river (m)		
				Cross-sections	
Creek	Culvert diameter (cm)	Dates of culvert replacement	Culvert (lower end)	Site 1	Site 2
1	38	10 - 25 July 1995	50	79	189
3	65	Not removed	0	42	190
4	45	Not removed	30	41	96
5(*a*) 5(*b*)	50 50	26 July- 11 August 1995	98	136	204

Table 1. Culvert diameters, dates of culvert replacement, and distances of culverts and creek cross-section sites from the southern arm of the Hunter River. Creek 5 had two culverts laid side by side, parenthetically labeled *a* and *b*. Replacement of culverts at Creeks 1 and 5 with bridges required a total of 33 days.

Results and Discussion

The culvert at Creek 1 retained water during receding tides and maintained a permanently flooded condition in the creek channel, even when water levels below the culvert were 65 cm lower than those above the culvert (Fig. 2). Relatively large tides, such as that of 25 May 1995, provided some tidal flushing above the culvert, but the flow of water was restricted and prevented levels above the culvert from closely tracking levels at the mouth of the creek. Relatively small tides, such as that of 6 June 1995, provided no flushing to Creek 1. For some time after the removal of the culvert at Creek 1, the remains of the temporary dam installed during construction works prevented drainage during low tide, as seen on 15 August 1995. The remains of the dam rapidly eroded, and by 3 October 1995 Creek 1 drained completely at low tide, leaving the

At Creek 5, two culverts set side by side restricted tidal flushing during large tides, limiting tidal range above the culverts to a fraction of that occurring near the mouth of the creek (Fig. 2). Removal of the culvert resulted in decreased restriction, allowing the tide above the bridge to follow the rising tide. Creek 5 continues to retain water at low tide, just as it did when culverts were intact, but minimum water depths have decreased. In addition, the velocity and volume of water flowing through Creek 5 increased dramatically following culvert removal, and what was once a permanently-flooded saline pond connected to the Hunter River by Creek 5 is now at least partly drained during low tide. Faunal communities in the creek will probably be altered by the increase in current velocity, and emergent plant assemblages may develop in low-lying areas that were permanently flooded before culvert removal. Changes in tidal flushing

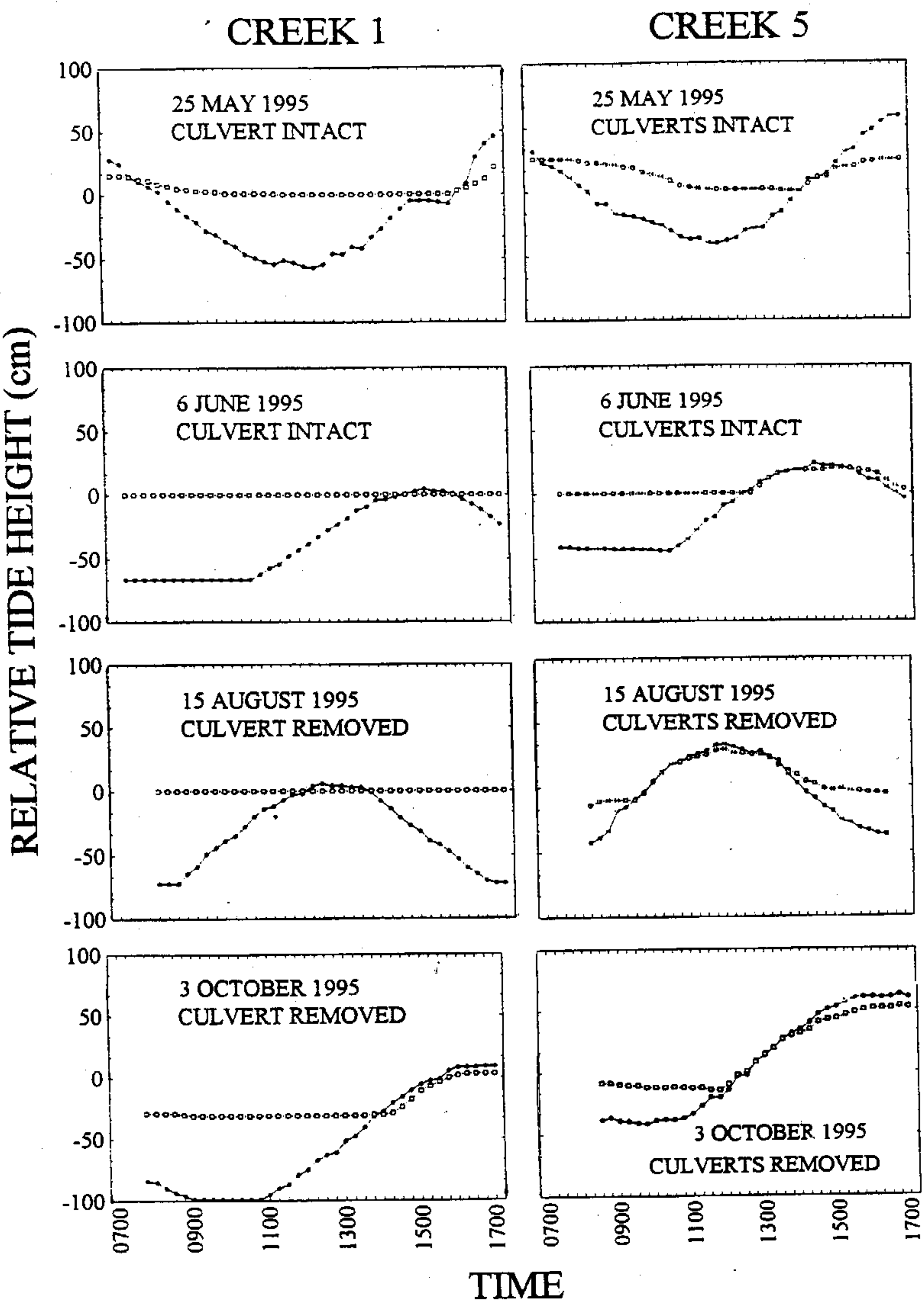

Figure 2: Water levels above (open squares) and below (shaded circles) culvert locations at two Kooragang Island tidal creeks where culverts were removed in July and early August 1995. The 0-cm level matches the bottom edge of culvert openings that existed before culvert removal.

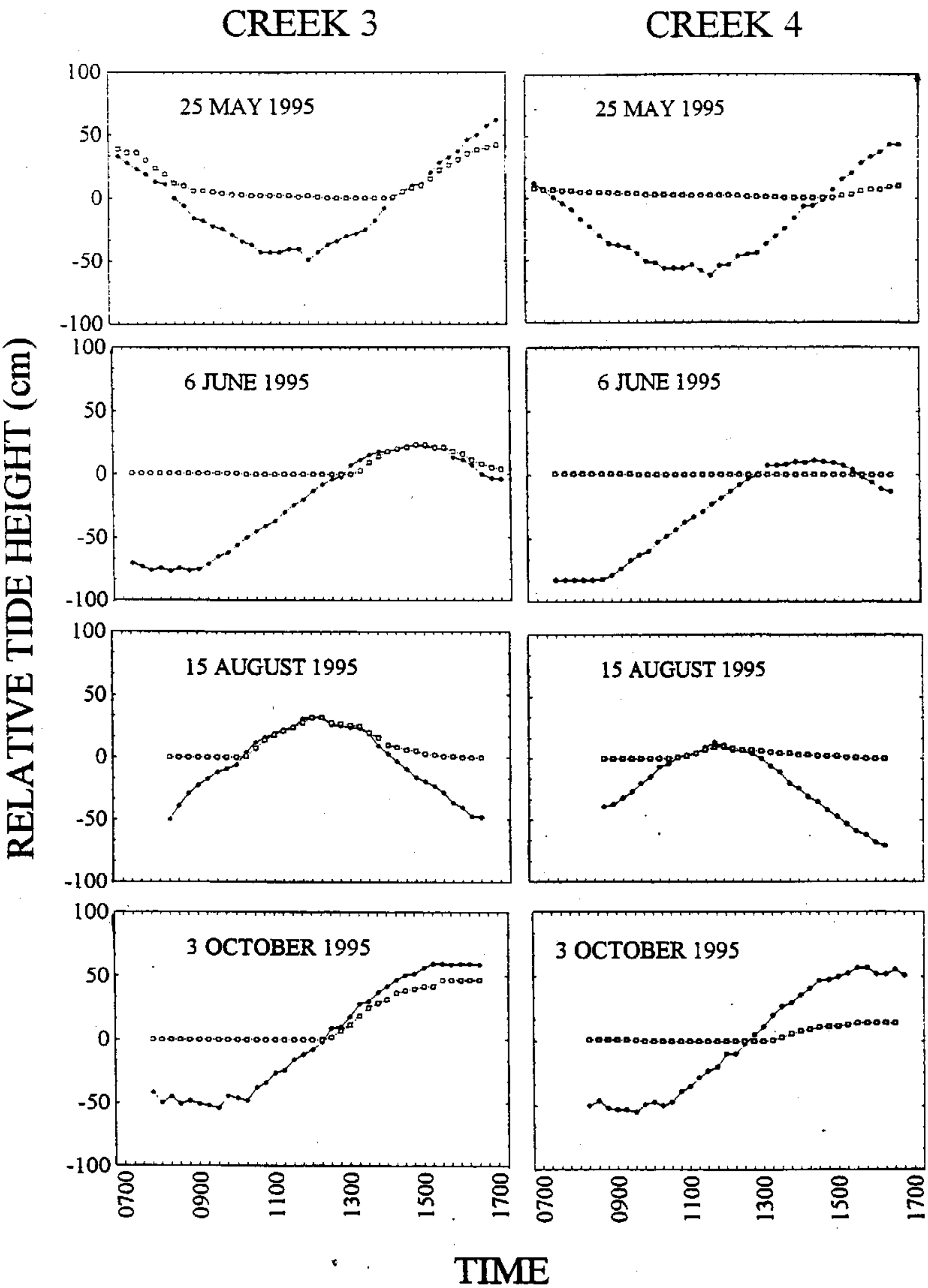

Figure 3: Water levels above (open squares) and below (shaded circles) culverts at two Kooragang Island tidal creeks where culverts were left intact. Differences in tidal flushing on different dates are smaller than differences seen on two creeks where culverts were removed. The 0-cm level matches the bottom edge of culvert openings.

appear more substantial in Creek 5 than Creek 1, suggesting the role of topography in the flushing of tidal creeks.

A comparison of Creeks 1 and 5 to Creeks 3 and 4 (Fig. 3) indicates that changes in Creeks 1 and 5 can be attributed to culvert removal and are not just reflecting fluctuating tidal ranges in the Hunter River. At Creeks 3 and 4, culverts continue to limit drainage during low tide. At Creek 4, the culvert appears to limit flushing at high tide by restricting the volume of water that can flow into the creek. Because both the low and the high tide are restricted in Creek 4, eventual removal of the Creek 4 culvert will probably have a greater impact on tidal flushing than removal of the culvert at Creek 3.

At Creek 1, some erosion has occurred at site 1, especially in what appears to be a newly forming channel at about 400 cm from the creek's edge (Fig. 4). At site 2 of Creek 1, accretion is slowly filling the channel. Substantial erosion occurred at site 1 of Creek 5, while less erosion is present at site 2 of Creek 5. The changes in Creeks 1 and 5, where culverts were removed, are more substantial than those of Creeks 3 and 4, where culverts were left intact. Slight changes in Creeks 3 and 4 show both erosion and accretion, as would be expected in tidal creeks under

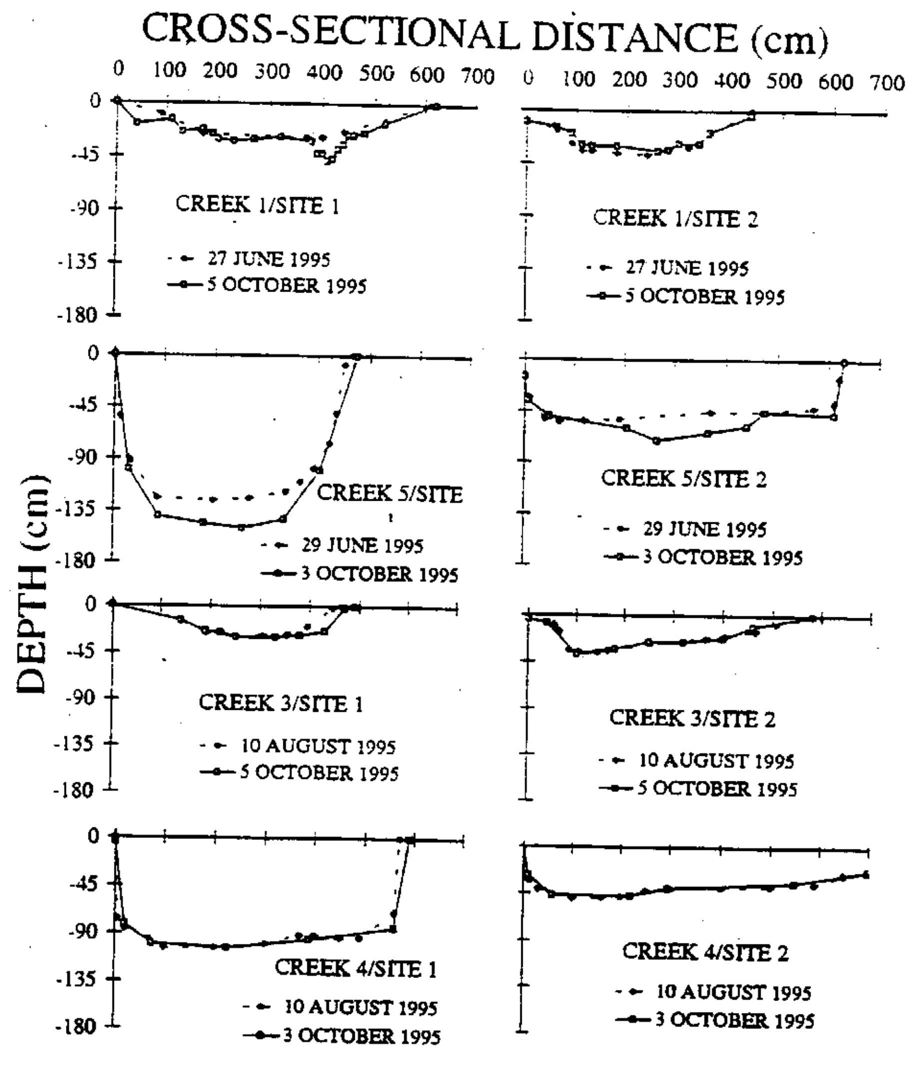

Figure 4: Cross-sections measured at two sites on each of four tidal creeks. Culverts restricting tidal flushing were removed from Creeks 1 and 5 in July and early August 1995, while culverts at Creeks 3 and 4 wer left intact.

approximately equilibrium conditions. High rates of erosion and accretion are expected to continue indefinitely in Creeks 1 and 5.

One of the objectives of the Kooragang Wetland Rehabilitation Project is to improve fisheries habitat in the lower Hunter River (Shortland Wetlands Centre Ltd. 1992). Because tidal flushing is associated with increased wetland productivity and because culverts were restricting tidal flow, a decision was made to remove culverts at two creeks. The impact of culvert removal on fish assemblages remains to be seen, but short-term observations show that culvert removal allows total drainage of Creek 1 at low tide and increased current velocity in Creek 5, both of which will be detrimental to some fish species. However, overall productivity of the wetlands associated with Creeks 1 and 5 may increase because of improved flushing, and productivity exported to the estuary may lead to improved conditions for estuarine fish species (Odum 1980). Ongoing Before-After/Control-Impact monitoring will assess changes in fish, bird, mosquito, and vegetation assemblages (Streever 1996), while additional research will assess the effect of tidal flushing on saltmarsh plants of Kooragang Island. A second objective of the Kooragang Wetland Rehabilitation Project is to provide managers with information relevant to estuarine wetland rehabilitation in Australia. A recently released report identifies over 1,300 structures that impede tidal flushing of creeks in New South Wales (Williams and Watford 1995). Changes attributed to culvert removal on Kooragang Island offer some insight to managers planning culvert removal at other sites.

Acknowledgments

We thank all of the volunteers who collected water level measurements, including Heidi Bischof, Nicole Brown, Robyn Carstairs, Michelle Callaghan-Perry, Caroline Slade, Ima Streever, and Michael Taylor. We thank the Kooragang Wetland Rehabilitation Project and the Project's coordinator, Peggy Svoboda, for financial and logistical support. Katherine Kelly conducted surveys of creek cross-sections. Rob Williams, Alan Genders, and an anonymous reviewer provided helpful comments on an initial draft of this paper.

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