PERGAMON

Marine Pollution Bulletin 46 (2003) 305–307

MARINE POLLUTION BULLETIN

www.elsevier.com/locate/marpolbul

Rocky shore intertidal zonation as a means of monitoring and assessing shoreline biodiversity recovery

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Keywords: Biodiversity recovery; Island Copper Mine; Beach dumps; Beach fill; Precautionary principle

1. Introduction

There are times when an old concept of science can be used for a new application. As an example, over many years to 1972, Stephenson and Stephenson (1949, 1972) developed the concept that there was a global pattern to biological intertidal zonation on rocky shores.

This pattern of zonation also occurs on rocky–stony beaches, wherever the rocks are large enough for biological colonization (Fig. 1). It is this feature which can nowadays be useful for assessing biodiversity recovery. Wherever a pre-existing marine shoreline has been covered with rock and stony fill, the appearance of the intertidal zones should follow a succession to the eventual "climax" or equilibrium community, i.e. the global pattern of zonation.

The following will show that the concept can be used for environmental monitoring purposes, an essential practical component of the Precautionary Principle (Tickner and Raffensperger, 1999). There are considerable logistic benefits in using the approach.

2. The Stephenson concept of a global pattern of intertidal zonation

The essence of the Stephensons' concept, in modern words, is that bands of different biodiversity occur progressively up a shoreline.

There is a wide highly visible mid-littoral zone, with dominant rockweeds giving some three dimensionality and cover to attached or mobile organisms. These are tolerant of, or depend on, periodic air exposure and seawater immersion, and usually include barnacles and mussels and their predators. This is topped by a supra-littoral fringe of almost bare rock but with periwinkles grazing on attached microalgae. There may be a splash zone with even fewer marine or sea-water tolerant organisms. Below the mid-littoral zone is an infra-littoral fringe of dense kelps and other algae, providing much cover for the fauna and flora. The mid-littoral zone is a distinct ecosystem, whereas the fringes are ecotones to the land and sea respectively.

So how is this old and well-established concept of biological zonation useful for monitoring the recovery of biodiversity after a shoreline ecosystem has been destroyed by smothering?

3. A contemporary application

The concept has been used at Island Copper Mine on the Pacific Coast of Canada to monitor biodiversity development along the rocky–stony shoreline face of a coastal waste rock dump. The fill covered the prior shoreline, and eliminated the organisms there.

The shoreline monitoring premise was that considerable biodiversity must have become established on the rocky–stony beach when the expected Stephenson rockweed (mid-littoral) zone (the equilibrium community) was established and was well populated. Also, when the zone's upper and lower fringes were visible as distinct coloured strips with brown, white, green or other coloured patches. In part this is because the algae present will have provided sufficient space in three dimensions to allow other, dependent, species to colonize.

Monitoring was undertaken 1996, 1997, 1998 and 1999, during the low summer tides June–August of any one year, by means of three vertical transects in each of the engineered bays, and other transects in between. I walked the transects recording the presence of the dominant and dependent forms, and their relative

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doi:10.1016/S0025-326X(02)00323-5

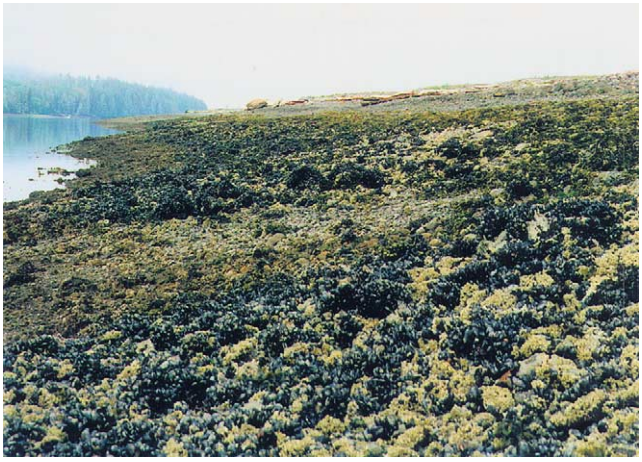

Fig. 1. Intertidal zonation on a rocky–stony beach. Dense growths of rockweed, mussels and barnacles are visible in this mid-littoral zone. The larger bare rocks of the supra-littoral fringe support periwinkles, which graze on periphyton. This site had a fully developed intertidal ecosystem in June 1999, three years after engineering work was completed on the shoreline face.

abundance. The recording for each form was conventionalized as not seen, occasional (<10 seen), abundant (10 to ~100 seen) and very abundant ($\gtrsim$ 100 seen)). Each monitoring site was photographed. Details of the results are provided in Ellis (2000, 2002).

In the first such survey in 1996, it was readily apparent by the records and photographs that the Stephenson mid-littoral zone and fringes in the oldest parts of the shoreline (two to four years since placement) were well formed. The newer part of the shoreline (four months) did not have the zones fully developed, and there was a sharp biological front between the old and the new (Fig. 2). By the following year (1997), the new part also had the zones fully formed, and the front had disappeared. This was confirmed in 1998 and 1999 (Fig. 1). Essentially the ecological succession had started within four months of settlement being possible, and the equilibrium community had formed within two years.

Fig. 2. The intertidal front on the shoreline of the waste rock dump at Island Copper Mine. In the distance, the two to four year-old rocky–stony beach had developed a typical rocky–stony shore mid-littoral zone and supra-littoral fringe. In the foreground, four months after final dump engineering, only the initial ecological succession of mixed algae settling mostly near low tide level was present.

4. Utility of the concept

The concept provides a very practical monitoring approach for documenting the recovery of shoreline biodiversity after complete obliteration for the following reasons:

1. Photographs provide convincing demonstration of the existence of the zones.
2. The transect records document the relative abundance of typical zone and fringe organisms.
3. The organisms do not need to be identified to species.

It is the third point which is novel in marine biodiversity assessment, and which makes the protocol unusually effective logistically and in costs. Normally in marine biodiversity assessments, all organisms collected should be identified to species and counted (per unit area sampled), which may take weeks or months. Only by species identification and quantitative sampling can accurate species richness and evenness counts be obtained for biodiversity assessment (Gaston and Spicer, 1998). On rocky shores, or rocky–stony shores, the Stephensons' concept means that when the zones are visible, and supporting counts (or relative abundance estimates) show that the typical organisms are present (in small or large numbers as appropriate), it is not necessary to identify them to species. The same kinds of organisms occur in the mid-littoral zone and its fringes throughout the world. Identification of the local species is superfluous. Not identifying to species, and not counting the numbers of each, substantially reduces the time needed (and costs) for the surveys, or alternatively allows extension of their scale at any one time.

This monitoring procedure, which allows not identifying and not counting each of many individual species, could only be developed for shoreline biodiversity assessment because of the well established documentation by the Stephensons of a global pattern of intertidal biological zonation. In modern terms the zonation pattern represents the equilibrium state for a rocky shore ecosystem anywhere in the world. An old concept has found a new use: for assessing biodiversity recovery on a smothered shoreline.

Acknowledgements

I am grateful to Island Copper Mine (BHP Billiton Inc.) for the opportunity to develop this concept, to

ICM environmental staff for working support especially Ian Horne, Environmental Manager during the time of these surveys, and to my wife Katharine Ellis for acting as on-site assistant.

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