MARINE RECLAMATION: RECOVERY OF THE SEA FLOOR COMMUNITY FOLLOWING MINE TAILING DISCHARGE

by Laura Taylor

Introduction

The majority of North American mining-related disturbances occur in terrestrial environments. The variable nature of impacts associated with these perturbations has initiated extensive research, the progression of which can be divided into three stages:

i) the initial impacts were investigated
ii) recovery processes in habitats disturbed by mining were compared to natural recovery processes
iii) information resulting from stages I and 2 were used to develop and implement reclamation and mitigation practices.

Increasingly, mining activities have begun to majorally affect aquatic environments, with tailing disposal being the primary cause of community disruption. The rise in popularity of aquatic tailing discharge has resulted as aquatic disposal is often cheaper than land impoundment, and circumvents the problem of ground water contamination common to terrestrial tailing deposits (Pedersen, 1984). In British Columbia, several mines release, or have released, tailings into aquatic systems (current examples are Amax into Alice Arm, Westmin into Buttle Lake, and island Copper into Rupert Inlet). Concern that such tailing disposal might ultimately adversely affect biota of receiving waters, prompted government and industry to implement comprehensive monitoring programs. These investigative programs involved initial impact assessment of mine tailing discharge. Such studies have provided the basis for the initiation of the same research progression pursued in damaged terrestrial systems. Aquatic researchers are now faced with the challenge of completing this process by investigating community recovery patterns (stage ii), to provide essential ecological information necessary for the development of aquatic reclamation and mitigation practices (stage iii).

In 1982, a study was initiated to examine benthic colonization of mine tailings in Rupert Inlet, Vancouver Island. This research, currently in progress, is a co-operative project with the author and Island Copper-Utah Mines. Island Copper employs a submarine tailing disposal system to minimize impact on primary productivity of pelagic communities in the photic zone. The success of Island Copper's submarine disposal has resulted in this method being the preferred technqiue for aquatic tailing discharge. Submarine release of tailings primarily affects bottom communities by reducing numbers of individuals and/or changing community structure (Island Copper Annual Reports, 1972-1982). Therefore, this investigation focuses upon marine benthic colonization of mine tailings, as this is the biological recovery process in the disturbed system. The primary research objective is to provide essential ecological information critically necessary for development of reclamation and mitigation practices for marine benthic communities affected by tailing discharge.

Impacts of Mine Tailing Discharge Upon Benthic Communities — Brief Review

I. <u>Impact Assessment - Ongoing Mine Tailing Discharge</u>

Information currently available on submarine tailing release concerns effects occurring while discharge is continuing (Island Copper Annual Reports, 1972-1982). Biological effects include reduction in numbers of organisms, and changes to community structure and composition (Island Copper Annual Reports, 1972-1982). These biotic disturbances are affected principally by alterations to four physical parameters:

i) high sedimentation rates can smother existing benthos and prevent larval settlement
ii) an unstable substrate may be created, thus rendering the bottom uninhabitable to many benthic organisms
iii) tailing deposition can alter sediment particle size, organic and inorganic content, all of which affect benthic communities
iv) accumulation of tailings may be so great that bottom depth is decreased, which can change benthic species composition.

The relative importance of these four factors in altering benthic community structure has not been elucidated. Clearly, the significance of each factor in determining community structure will be determined by physical and chemical environments of receiving waters. In Rupert Inlet, benthic organisms are known to be affected by the first two factors (Island Copper Annual Reports, 1972-1982). The third and fourth may also play a role in Rupert Inlet, however, the extent of their influence has not been examined. To determine the precise biological mechanisms through which initial impact is effected, and their relative importance, studies are now being directed to examine benthic community dynamics in disturbed and undisturbed systems. The information derived will be particularly useful in development of mitigation procedures for marine tailing disposal operations.

2. <u>Impact Assessment - Colonization</u>

Upon ceasation of mine tailing discharge, impact upon resident benthic communities will primarily be caused by the presence of a tailing substrate and its affect upon local water quality. These perturbations will mainly affect benthic colonization and community development. As the widespread use of aquatic tailing disposal is a relatively new phenomenon, investigations into disruptions to community development following tailing discharge are in an early stage.

Colonization proceeds through a common successional pattern in terrestrial and aquatic systems (Figure I). Initially, new space is invaded by opportunistic species. These are characterized by short life cycles and rapid growth of individuals and populations (Odum, 1969). Typically, these organisms modify their environment, enabling other species to inhabit the area. Gradually, opportunists are replaced through competition and predation by an intermediate group with less rapid growth and longer life cycles. These, in turn, change their environment, giving way to equilibrium species which are long-lived and slow-growing (Odum, 1969). This final community persists as long as the system is not disturbed. Disturbance results in the community shifting back to an earlier stage in succession. The time required to reach an equilibrium community is extremely variable and is dependent upon a multitude of factors in the surrounding environment.

Research Objectives

The aim of this study is to examine the processes involved in benthic colonization of mine tailings, to provide ecological data for use by government and industry in development of management practices. To clearly delineate the inquiry, the research objective has been divided into four categories:

i) what species colonize tailings?
ii) what is the sequential pattern of species as the community develops?
iii) at what rate does colonization occur?
iv) what affects the colonization process (specifically — how does seasonality affect colonization)?

If these four questions are related to the island colonization curve (MacArthur and Wilson, 1967) (Figure I), their place in the colonization process is clarified. The first question translates to an examination of the species composition on the y axis. Assessment of changes in species composition along the curve addresses question two. Question three involves determining the slope of the curve. Elucidation of factors that change curve shape, or species composition would

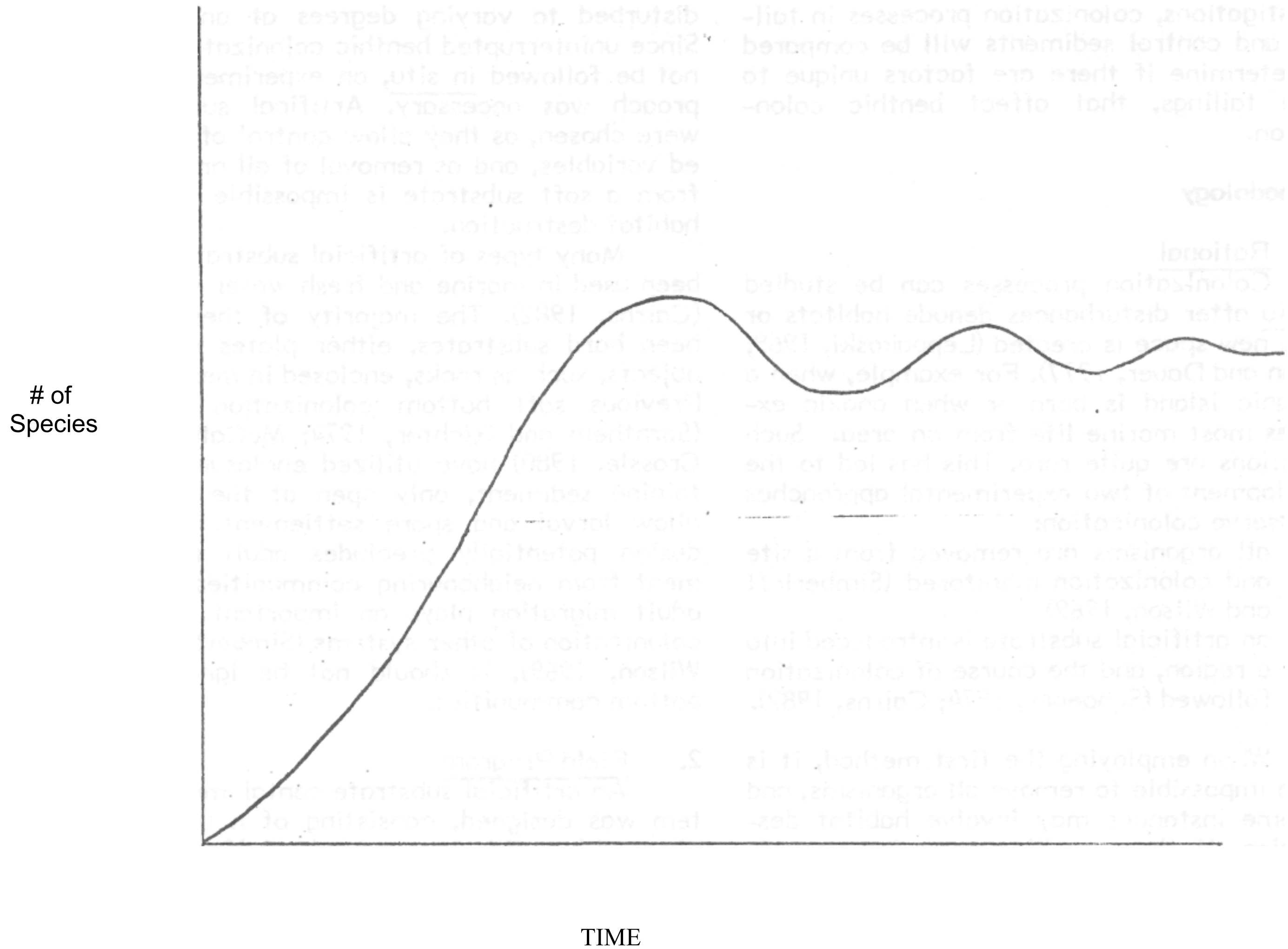

Figure 1
The island colonization curve of MacArthur and Wilson (1967)
over time number of species increase until a dynamic equilibrium is reached

answer question four. A multitude of factors could potentially change curve shape. Therefore, this study is limited to the examination of only one of these — the effect seasonality has on colonization. Throughout all these investigations, colonization processes in tailings and control sediments will be compared to determine if there are factors unique to mine tailings, that affect benthic colonization.

Methodology

I. Rational

Colonization processes can be studied in situ after disturbances denude habitats or when new space is created (Leppakoski, 1969; Simon and Dauer, 1977). For example, when a volcanic island is born or when anoxia excludes most marine life from an area. Such situations are quite rare. This has led to the development of two experimental approaches to observe colonization:

i) all organisms are removed from a site and colonization monitored (Simberloff and Wilson, 1969)
ii) an artificial substrate is introduced into a region, and the course of colonization followed (Schoener, 1974; Cairns, 1982).

When employing the first method, it is often impossible to remove all organisms, and in some instances may involve habitat destruction. If these problems are insurmountable, artifical substrates can be utilized. This later technique has the advantage of allowing researchers to control numerous variables while still exposing organisms to the complexities of the field environment.

Monitoring benthic colonization and succession of existing mine tailings in Rupert Inlet is not possible as Island Copper Mine is currently discharging tailings and proposes to do so for at least another twelve years. 40,000 tons of tailings are released per day, which have covered most of the Rupert Inlet seafloor (Island Copper Annual Reports, 1972-1982). Tailings are released at a depth of 50 m, where they form a turbidity current that moves away from the outfall pipe. The position of this current within the water column is not static, rather it moves in an apparently random manner. Sedimentation rates, therefore, vary both spatially and temporally, thus colonizing communities may be disturbed to varying degrees at any time. Since uninterrupted benthic colonization cannot be followed in situ, an experimental approach was necessary. Artifical substrates were chosen, as they allow control of selected variables, and as removal of all organisms from a soft substrate is impossible without habitat destruction.

Many types of artificial substrates have been used in marine and fresh water systems (Cairns, 1982). The majority of these have been hard substrates, either plates or solid objects, such as rocks, enclosed in mesh bags. Previous soft bottom colonization studies (Sarnthein and Richter, 1974; McCall, 1978; Grassle, 1980) have utilized enclosures containing sediment, only open at the top, to allow larval and spore settlement. Such a design potentially precludes adult recruitment from neighbouring communities. Since adult migration plays an important role in colonization of other systems (Simberloff and Wilson, 1969), it should not be ignored in bottom communities.

2. Field Program

An artificial substrate containment system was designed, consisting of a 0.25 m plywood box filled to a depth of IO cm with tailings (experimental), or fine white marble sand (control). Each box had only three sides, allowing adult immigration along one end. Once every two months, experimental units, consisting of two experimental and two control boxes, were placed on the bottom of Rupert Inlet. These units were left in place for I, 2, 4, 8, and 12 months (Figure 2). This permitted examination of community development through time, together with seasonal variability.

The artificial substrate containment system was frozen to eliminate sediment loss while lowering through the water column. Retrieval was accomplished by S.C.U.B.A. divers who secured the integrity of the

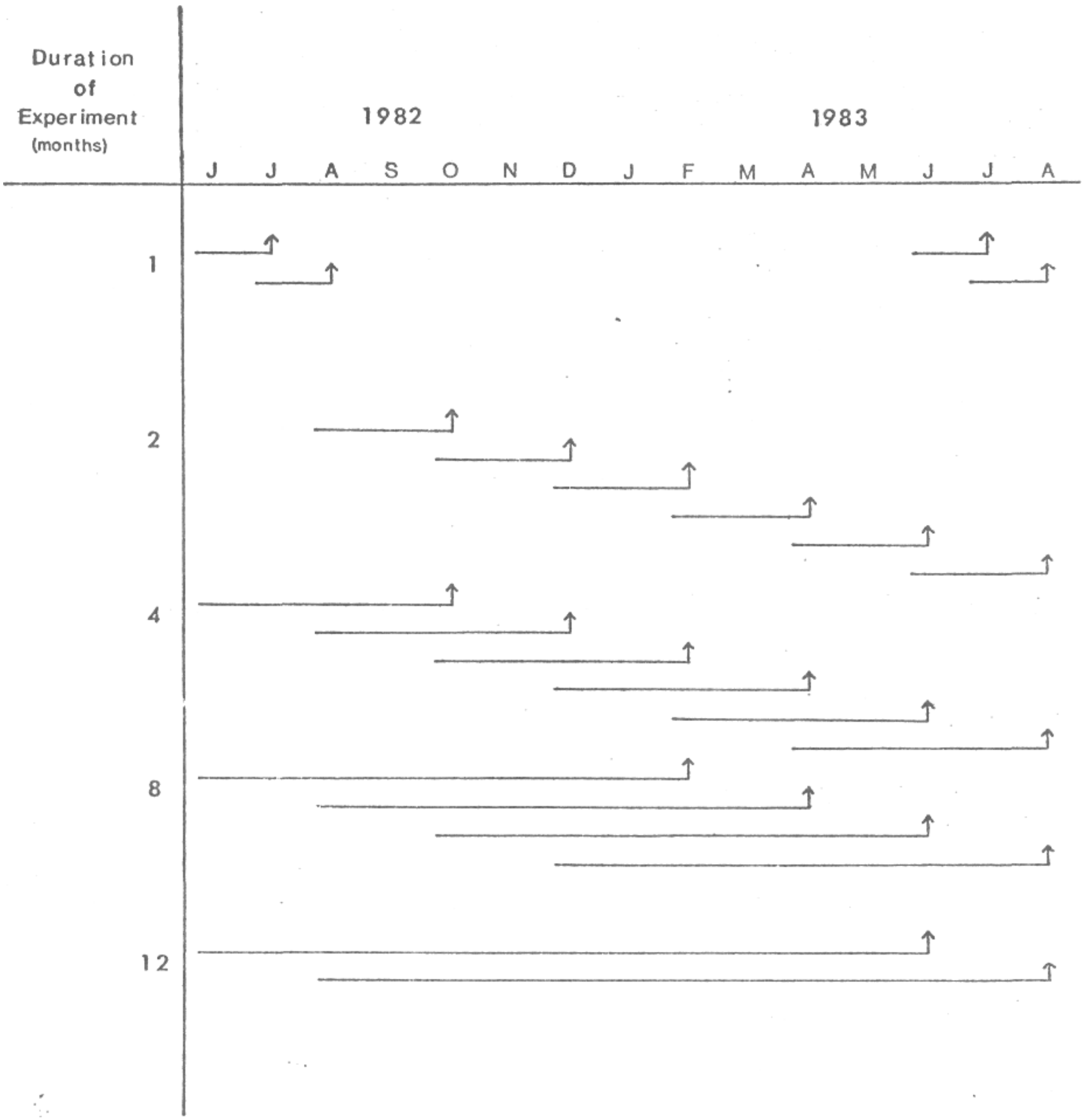

Figure 2

Experimental design for benthic colonization studies

Each line represents a set of artificial substrate boxes. The length of the line indicates the duration of exposure of the set. Arrows show the time of retrieval.

containment system by attaching lids to each box, which minimized sediment loss. At the surface, boxes were randomly cored and samples sieved. The field program terminated in August 1983. Species identification and data analysis are currently in progress.

3. Problems Encountered in Field Experiments

The major problem arising during field sampling was the loss of several experimental units. High winds and waves caused movement or disappearance of marker buoys designating location of experimental units. This, together with extremely high turbidity (poor visibility when diving during placement and removal operations), sometimes made units impossible to find. Disruption of field programs and loss of samples and equipment is by no means uncommon when conducting marine investigations. However, loss of experimental units could be reduced in future research by fastening marker buoys more securely, and by devising a box relocation technique that did not require visual identification.

Another problem that emerged upon termination of sampling, was that sedimentation from the water column changed heavy metal concentrations in artificial substrates. Over time, control boxes were becoming contaminaled by sedimentation, while heavy metal levels in experimental boxes were being reduced. This change in heavy metal content was probably concentrated at the substrate surface. It is this surface layer that settling larvae perceive, so a change in this upper layer may influence larval settlement. Therefore, given sufficient time, communities in control and experimental boxes may converge as the environments become functionally similar.

Sedimentation may rapidly change benthic environments once tailing discharge ceases. Presently this remains untested, which demonstrates the drawbacks inherent in extrapolations from experimental to natural conditions, and from the situation at one location to another. Ideally, investigations should be implemented in the environment under study, i.e. for this research, an examination of in situ benthic colonization in a system where tailing discharge had recently terminated. Unfortunately, such environments are not always available when answers are required. Currently, Amax on Alice Arm has ceased tailing discharge, thus providing a unique opportunity for in situ examination of benthic colonization. Hopefully, studies will be done in this area, as they would undoubtedly supply valuable information to the field of benthic colonization research.

Possible Results

Benthic colonization of mine tailings could proceed along a number of paths. A tailing substrate may not affect colonization. Alternately, colonization and succession may be slowed, although the eventual equilibrium community would not be changed. A further possibility is the halting of community succession at some point, until the cause of this is removed from the system. Finally, the time frame of development may not be influenced, but the resulting tailing community may differ from the control in species composition or abundance.

Conclusion

Information on benthic colonization will further improve our understanding of the long-term impacts of mine tailing discharge upon benthic communities. Such knowledge is required to determine the recovery rate of benthic communities, and in establishing whether they eventually return to their pre-discharge state, or if a new and different community results. Further, benthic colonization studies may be useful in ascertaining if, and how, to diminish impacts by providing necessary background information for the development of reclamation and mitigation procedures. Thus, through implementation of sound resource management practices, it may be possible to substantially improve benthic habitat. Environmental regulatory agencies and industry may also refer to benthic colonization research when designing monitoring procedures, and establishing regulations for future marine tailing disposal systems.

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