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1. Introduction

1.1. General introduction

River ecosystems are vulnerable to degradation because of the complexity of water properties, the interaction between rivers and their surrounding areas and the proximity of human populations (Dobson and Frid, 1998; Molnar *et al*., 2002). The impact of terrestrial changes on rivers will be more serious in areas with a high population density. Urbanisation and agricultural development are the major causes of aquatic community alterations (Lim, 2003). The increasing demand for freshwater resources generated by population growth, urbanisation, industrialisation and irrigation will result in a decline or loss of freshwater biota (Dudgeon, 1992; Choy, 1996).

There are two main reasons for using fish to monitor stream habitats. The first reason is that fish communities are enormously diverse with different species reflecting different environmental conditions. Out of 25,000 known fish species, 10,000 species (over 40%) are found exclusively in freshwaters (Kottelat and Whitten, 1996). The second reason is that fish species have major effects on the distribution and abundance of other aquatic organisms in their habitats. Predation by fish produces strong cascading effects on aquatic biota (Power, 1990; Leveque, 1997). For example, small predatory insects and fish fry reduce the number of midges (Chironomids) colonising cladophora. Consequently, the densities of damselfly nymphs and other small predators increase due to lack of predation because algivorous chironomids are abundant. Chironomids in turn, dramatically reduce algae standing crops (Power, 1992; Fernando, 1994).

Understanding how the structure of fish community changes spatially along environmental gradients continues to be a major interest in river ecology, especially regarding the implications of these changes for river conservation and management (Schlosser, 1990). The importance of the environmental gradient has been discussed at many different levels, including regional patterns in species (Gorman and Karr, 1978; Coad, 1980; Schlosser, 1982), distribution, longitudinal changes in community composition (Oberdorff and Hughes 1992; Oberdorff *et al.,* 1993; Goren and Ortal, 1999) and microhabitat segregation between a pool and riffle (Moyle and Vondracek, 1985).

However, most of these studies dealt with rivers in temperate regions and focused on biogeography rather than on the ecology of fish communities. There are 5,886 rivers in Indonesia (Directorate General of Water Resource Development, 1991), but a little is known about the ecology of freshwater fish in Indonesia. There is not even a report illustrating the situation in Central Java. The upper parts of streams have been deforested, which increases the temperature and sediment load. The course of their flows are threatened by dam construction which eradicates high gradient sections and alters the flow pattern down stream or causes channelisation which reduces the heterogeneity of river beds and the number of available ecological niches (Kottelat and Whitten, 1996). Commonly, rivers receive organic matter from agricultural areas, housing and traditional food industry, which cause destruction of stream habitats, and degradation of water quality.

The Indonesian fish fauna is poorly known, as is demonstrated by the list of additions and discoveries of new species. About 18.1% of the known fish species in Indonesia have been discovered only in four years before 1993 (Kottelat *et al.,* 1993). Considering the lack of scientific information and the crucial role of rivers in human lives, more research is essential on freshwater fish communities to enable the development of a biological monitoring system (Raven and Wilson, 1992; Prins and Wind, 1993). Research is also necessary to determine the impacts of human activities on river habitats.

1.2. General conditions in tropical rivers

Tropical Asian rivers are characterised by their seasonal fluctuation of flows (Lowe-McConnell, 1987). Most tropical rivers have an annual cycle dictated by the seasonality of rainfall. Fluctuations in the discharge rate can have marked effects on the chemical composition of the freshwater. Usually, the concentration of ions in waters is at a maximum level during the dry season. This effect may be particularly significant with respect to nitrate (Payne, 1986). One or two peaks in discharge cause temporary declines in phytoplankton, zooplankton and zoobenthos biomass. However, it also leads to the inundation of river floodplains and significant interactions with the land surrounding the river.

Among the diverse human impacts on rivers, there are three main threats. The first is the degradation of drainage basins, especially due to deforestation. This impact causes an increase in suspended sediment loads and flooding (Zakaria Ismail, 1994). Excessive flooding siltation changes river habitats and causes species decline. Observations in the Gombak River in Malaysia demonstrated the reduction of fish species due to land development. In 1969, 27 species were recorded but data from 1985 indicated that seven fish species have completely vanished, and five years later four more species had disappeared (Zakaria Ismail, 1994).

The second threat is river regulation and control. Flow regulation changes the magnitude and extent of floodplain inundation and land water interactions. Fish breeding migrations may be disrupted because dams block migration routes and change flow regimes.

The third threat is river pollution. Untreated waste is a particular problem in densely populated areas and pollution by industrial effluents is a serious problem in tropical rivers (Dudgeon, 1992). Most pollution comes from domestic, agricultural or industrial wastes and can be totally toxic, killing all the fish species present, or selectively destroying a few sensitive species (Maitland, 1995; Kottelat and Whitten, 1996). For example, thousand tonnes of freshwater fish are killed by poisonous wastes every year in the floating net fishery of the Saguling, Cirata and Jatiluhur reservoirs in West Java (Lehmusluoto, 1993).

1.3. Tropical freshwater fish species

The freshwater fish fauna of Southeast Asia is diverse. Unfortunately, up to date references on these fish communities are scarce. Members of Ostariophysi dominate the tropical fish species, and in southern Asia the predominant groups are the carp family Cyprinidae (Rainboth, 1991) and the catfishes Siluroidae. The family of Cyprinidae alone contributes more than a third of the known species, and together with the Siluroidae, they contribute almost 60% to the total diversity of tropical fish species (Payne, 1986).

Zakaria Ismail (1994) classified the pattern of fish distribution of Southeast Asia into five zoogeographic regions. These are: the Salween Basin in Burma; the Indo-Chinese Peninsula which includes the Mekong, Chao Phraya and Mae Khlong river drainages in Thailand and Kampuchea; the Malay Peninsula; the Indo-Malayan Archipelago and the Philippines. The Indo-Malayan Archipelago includes the islands of Sumatra, Borneo and Java. This region not only possesses a highly diverse fish community with more than 400 species, but also has many endemic species within the families Belontiidae, Helostomatidae, Osphronemidae and Luciocephalidae.

On the island Borneo, about 290 species were present in the Kapuas River, which supports the most diverse fish community in this region (Roberts, 1989). A total of 147 indigenous freshwater fish species has been identified from the Mahakam River (Christensen, 1992). A total of 25 species of freshwater fish was recorded from the Belalong River in Sabah (North Borneo). Most of them are surface, pelagic and demersal dwellers (Choy *et al*., 1996). The majority of the species in the benthic zone belong to the family Cyprinidae. A study in the Northern Borneo river illustrated that the most suitable aquatic environment for fish life is water with a pH between 6.5 - 9.0, a dissolved oxygen content greater than 5 mg/l, and with total suspended solids (TSS) less than 80 mg/l (Choy, 1996).

Whitten *et al*. (1996) reported that the abundance and diversity of Java's indigenous fishes have declined because of the loss of forest, pollution, digging sediment and interruption of the river dams. The total number of freshwater fish species in Java is 132 species. Of which 12 species (9%) are endemic: six species from the Cyprinidae, one species each from the Balitoridae, the Cobitidae, the Akysidae, the Hemiramphidae and two species from the Gobiidae (Kottelat *et al*., 1993; Kottelat and Whitten, 1996).

1.4. Organic pollution in rivers

There are various definitions of pollution, however, a widely used definition is: "the introduction of substances or energy by human into the environment liable to cause hazards to human health, harm to living resources and ecological systems, damage to structure or amenity or interference with legitimate uses of the environment" (Holdgate, 1979; Safina, 2001). Organic pollution is considered to be the oldest and most widespread type of pollution and it is a very complex phenomenon. The major sources of organic pollution are from domestic, agricultural and industrial wastes with varying compositions depending on their origin. Domestic wastes include human excreta and a small proportion from food preparation, personal washing, laundry and surface drainage. Commonly, domestic waste contains high levels of phosphate, whereas agricultural waste contains many nutrients, especially nitrate from artificial fertilisers (Gray, 1989).

In rivers, organic matter decomposes naturally by bacteria and this decomposition process requires oxygen (Gray, 1989). The oxygen consumption in this process increases proportionally to the amount of organic matter. When a river receives a large amount of organic matter, the rate of oxygen consumption for decomposition is greater than the rate of re-aeration, even though other processes such as photosynthesis, sedimentation and oxidation of bottom deposits contribute oxygen to the water. As a result, the dissolved oxygen level drops and an oxygen sag curve develops. Under extreme conditions, the water may become anaerobic (Hellawell, 1986; Mason, 1991; Law, 1993). The availability of dissolved oxygen is crucial to the survival of aquatic life. A decrease of the dissolved oxygen level eliminates the sensitive aquatic organisms and increases the number of tolerant species, especially the decomposer species in the macroinvertebrate community and fish capable of breathing atmospheric air or of using the oxygen rich surface layer such as guppies *Poecilia reticulata* (Kottelat *et al*., 1993). Although they are well documented for temperate fishes, details on toxicological effects of organic pollution on tropical fishes are difficult to find. (Siligato and Böhmer, 2001).

Decomposition of organic matter itself produces toxic substances. Decomposition involves two major processes; hydrolytic degradation occurs in aerobic conditions, the high molecular weight organic substances such as proteins being degraded into low molecular weight compounds, for instance glucose, amino acid and cellobiose. Non-hydrolytic oxidation occurs in anaerobic conditions. The low molecular weight compounds are mineralised to inorganic compounds such as ammonia, hydrogen sulphate and methane. These compounds are toxic to aquatic life (Alabaster and Lloyd, 1982; Wetzel and Likens, 1991).

2. Background and objectives

2.1. Background

Detecting the human impacts on riverine systems is challenging because of the diverse biological, chemical, hydrological and geophysical components that must be assessed. A long history of human alteration has ensured that there are no Asian rivers in pristine condition and many are in a damaged state. Although there have been many studies on the ecological effect of pollution in South East Asian Rivers, few studies have been conducted in Indonesia (Soeroto and Tungka, 1996; Booth *et al.,* 2001; Sudaryati *et al.,* 2001). These few studies mostly examined the impacts of pollution from point industrial sources such as a study in the Ciliwung River (Palupi *et al.,* 1995; Walsh *et al.,* 2002). On the other hand, almost all rivers in Indonesia have been reported to be polluted by domestic wastes and recently cases of this type of pollution have increased (Saeni *et al.,* 1980; Nontji, 1994). The extent of domestic waste treatment in Indonesia is inadequate; this public service covers less than 50% of the nation population (Palupi *et al.,* 1995). Moreover, pollution from agriculture or non-point source is largely uncontrolled and most rivers are too contaminated (Dudgeon, 1999).

Fish communities in Javan freshwater habitats are threatened by deforestation, pollution and over-fishing especially with poisons (Dudgeon, 1999). The destruction of the freshwater habitats is claimed to be one of the main reasons why half the number of fish species from Java, which presented up to the middle of the last century, can no longer be found on the island (Kottelat and Whitten, 1996). Several studies on the longitudinal succession of tropical stream fish species in Sabah, Malaysia, have reported an impact of water quality change due to deforestation (e.g. Choy, 1996; Martin-Smith, 1998a,b). Conversion of forest to coffee plantations in East Java leads to an increase of total phosphorus from 10 σg/l to 70σg/l (Walsh *et al.,* 2002).

Numerous rivers in Java are in a poor condition due to environmental degradation and an ever- increasing demand on the resource base which is an inevitable consequence of population growth (Dugdeon, 1999; 2000). The total pollution load produced by inhabitants within the Brantas River, East Java, was about 380 tonnes of Biochemical Oxygen Demand (BOD) per day (Sudaryanti *et al.,* 2001). A case study in Toba Lake, Sumatra, illustrated that agricultural waste from farming areas around the lake resulted in it being the highly oligotrophic and causing native indigenious fish such as *Neolissochilus* sp to become scarce. Heavily polluted water has been reported in sites near human settlements and in mouthparts (Saragih and Sunito, 2001).

Some rivers are poisoned regularly for fishing, often as frequently as once a week or even more (Kottelat and Whitten, 1996; Dudgeon, 1999). The frequency of people coming to the rivers has been increasing since the economic crisis in 1997, and poisoned rivers have become a serious problem. Local people traditionally used poisons from plant materials (natural phytochemical compound), but nowadays, they tend to use commercial pesticides as poison for fishing (Kottelat and Whitten, 1996). Traditional poisons, mostly taken from *Derris* sp are biodegradable and non–persistent, whereas pesticides and artificial toxins are not (Dudgeon, 2000). Moreover the concentration of pesticides used to disable fish could be extremely lethal or harmful to other aquatic organisms. Under such unnatural conditions, most aquatic organisms will rapidly disappear.

This study attempts to determine the impact of non-point pollution on the fish community of the Logawa River, Central Java, Indonesia. The pollution comes mainly from agricultural areas and human settlements, which are the predominant land use types in the surrounding areas.

2.2. Hypotheses and questions

2.2.1. Hypotheses

This study is based on the following hypotheses:

1. The Logawa River receives organic materials from its surrounding areas.
2. Different type of land use in surrounding areas contribute different types of organic matter which leads to different levels of organic pollution in terms of water quality.

3. The alteration of the water quality of the Logawa River will lead to changes in abundance and diversity of fish community

2.2.2. Questions

The following questions were formulated to form the scope of this study:

1. Does the Logawa River receive organic materials from its surrounding areas?
2. To what extent does the organic loading from the surrounding areas affect the water quality of Logawa River?
3. Is the change in water quality mainly controlled by the organic supply from surrounding areas of the Logawa River?
4. To what extent does the change of water quality affect aquatic organisms communities in the Logawa River, especially fish species?
5. What fish species are still present in the Logawa River?
6. Is there a relationship between the changes of fish communities and the change of water quality in the Logawa River?

2.3. Principal objectives

The principal objectives of this study were:

1. To describe the link between the introduction of organic materials from surrounding areas to the Logawa River and the change of water quality of this river.
2. To describe how fish communities (abundance and diversity) change with different levels of organic pollution from surrounding areas of the Logawa River.
3. To determine how specific freshwater fish species respond to organic pollution condition.