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Vertical Sediment Drilling Technique in Fish-Pond Areas of Lake Limboto

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Abstract: Lake Limboto in Gorontalo is an essential ecosystem for local communities, particularly fishermen, yet fish-pond activities have increased sedimentation and accelerated the lake's degradation. Effective conservation efforts require sediment-characterization analysis, including vertical sediment profiles in pond areas, which has been limited by the lack of appropriate drilling techniques. This study aims to evaluate a vertical sediment-sampling technique in fish-pond zones using a survey method and shallow drilling with an XY-1A spindle-type drilling machine at depths of 1–15 meters. The results indicate that drilling stability is strongly influenced by the structural integrity of the machine's support base, particularly due to water currents and waves in the lake. This drilling technique is recommended for sediment sampling in Lake Limboto, especially in pond areas, and contributes to the advancement of sediment-drilling methods in similar aquatic environments.

Keywords: Aquaculture area, Lake Limboto, Vertical sediment, Drilling technique

Abstrak: *Danau Limboto di Gorontalo merupakan ekosistem penting bagi masyarakat, terutama nelayan, namun aktivitas tambak ikan meningkatkan sedimentasi dan mempercepat degradasi danau. Upaya konservasi membutuhkan analisis karakteristik sedimen, termasuk sedimen vertikal di area tambak, yang selama ini terkendala oleh teknik pengeboran yang sesuai. Penelitian ini bertujuan mengevaluasi teknik pengambilan sampel sedimen vertikal di area tambak menggunakan metode survei dan bor dangkal mesin spindel XY-1A dengan kedalaman pengeboran 1–15 meter. Hasil menunjukkan bahwa stabilitas posisi bor sangat dipengaruhi oleh kondisi penyangga di area tambak karena adanya arus dan gelombang danau. Teknik pengeboran ini direkomendasikan sebagai metode pengambilan sedimen di Danau Limboto dan memberikan kontribusi bagi pengembangan metode pengeboran sedimen di perairan serupa.*

Kata Kunci: *Area tambak, Danau Limboto, Sedimen vertikal, Teknik pengeboran*

INTRODUCTION

A lake is a depression on the Earth's surface filled with water, forming a stagnant freshwater ecosystem that is larger in area than a pond (Uno & Thalib, 2020). Lake Limboto, located in Gorontalo Province, is the largest natural lake in the region (Baga et al., 2024). The lake spans two administrative areas, with approximately 70% lying within Gorontalo Regency and the remaining 30% within Gorontalo City (Mustakim et al., 2021). Lake Limboto also serves as one of the region's primary natural resources and a major source of livelihood for communities living along its shores.

Local residents utilize the lake as an economic base through fisheries-related activities, including fishing, aquaculture, and fish cultivation (Hasim, 2018; Krismono et al., 2018).

According to Yunginger et al. (2018), Lake Limboto has undergone significant environmental changes, including a reduction in surface area and progressive shallowing of its bed. Historical records indicate that in 1932, the lake covered an area of 7,000 hectares with a maximum depth of 30 meters (Mahmud et al., 2020; Kimijima et al., 2022). By 2023, however, its surface area had shrunk to approximately 26.09 square kilometers, with a maximum depth of 4 meters and an average depth of 2.83 meters (Yunginger et al., 2024). These environmental changes are among the contributing factors to ongoing ecological problems in the Lake Limboto watershed (Lihawa & Dunggio, 2022).

The environmental deterioration of Lake Limboto is primarily driven by high sedimentation rates originating from surrounding river catchments (Yunginger et al., 2022). Various rivers flowing into the lake transport sediment derived from erosion in agricultural lands, residential areas, and deforested upstream zones. As a result, this material gradually settles and accumulates on the lake floor. In addition, the rapid proliferation of aquatic weeds such as water hyacinth contributes substantial biomass, which eventually sinks after the plants die and decompose, thereby exacerbating the shallowing process.

Sediment is among the most critical natural resources on Earth (Rangsiwanichpong & Melesse, 2022). Sedimentation refers to the deposition of material transported by erosion and weathering through water, wind, or other agents into a receiving basin, typically a low-lying depression (Rahmah, 2019). Sedimentation in Lake Limboto has been further intensified by the growth of aquaculture activities, particularly fish ponds and floating net cages (KJA) (Alfianto & Cecilia, 2020; Junus, 2024). These activities generate large quantities of organic waste from uneaten fish feed and fish excrement, which sink directly to the lake bottom. As noted by Fitrani and Wijayanti (2020), fish-pond activities are significant contributors to sediment accumulation due to the deposition of excess feed on the lake floor (Farha et al., 2022). Moreover, waste materials from fisheries operations in Lake Limboto—including nets and bamboo structures—are frequently left abandoned in the water, further contributing to the accelerating sedimentation rate in the area.

Conservation efforts for Lake Limboto have become a priority for local government, researchers, and communities, particularly given the increasingly critical state of its degradation. Various strategies have been designed, ranging from watershed rehabilitation and regulation of agricultural and aquaculture activities to sediment dredging programs. However, effective conservation strategies must be grounded in accurate scientific data concerning sediment dynamics, sedimentation sources, and the spatial distribution of sediment materials within the lake. Such information is essential for designing targeted conservation interventions, particularly those aimed at reducing sedimentation rates and gradually restoring the lake's ecological condition. Thus, studies on sediment characteristics and appropriate sampling methodologies constitute a vital component of long-term conservation efforts.

This study was conducted with the objective of obtaining intact vertical sediment samples from the fish-pond areas of Lake Limboto by applying a vertical sediment-drilling technique. Vertical sediment sampling involves the extraction of subsurface samples at varying depths (Nurhidayah et al., 2020). This approach is employed to identify the stratigraphic arrangement of sediment layers, thereby providing a basis for understanding sedimentation patterns in the surrounding water body (Winarto et al., 2015). Furthermore, Wurzbacher et al. (2017) emphasized that vertical sediment research is valuable for its capacity to yield detailed information on sediment characteristics at a given site, enabling the assessment and evaluation of existing sediment conditions.

A precise and efficient drilling technique provides a clear picture of the sedimentation profile over time, thereby revealing the sediment dynamics occurring within the lake environment. The findings of this study are expected to serve as a reference for selecting and applying appropriate sediment-drilling techniques suited to lacustrine conditions, particularly in fish-pond areas where

sediment characteristics are more complex. Furthermore, the vertical sediment data obtained will form a critical foundation for analyzing sediment characteristics, with the aim of formulating science-based solutions for the sustainable conservation of Lake Limboto.

METHODS

This study employed a survey method combined with vertical sediment drilling to obtain intact vertical sediment cores from Lake Limboto, specifically from its fish-pond areas. The instrument used was an XY-1A spindle-type drilling machine, capable of reaching depths of up to 180 meters.

Figure 1. XY-1A Spindle-Type Drilling Machine

The sediment sampling procedure using the XY-1A spindle drilling machine began with attaching the drill bit to the end of the drill rod. The drilling machine was then prepared, activated, and adjusted by regulating the drilling speed and pressure according to the characteristics of the sediment to be sampled. Once the machine was ready, drilling was carried out by gradually inserting the drill rod into the sediment until the target depth was reached. After achieving the desired depth, the drill rod was slowly withdrawn to recover the sediment sample from the borehole. To facilitate sediment extraction, a water pump with sufficient capacity to generate the required pressure was prepared and connected to the upper section of the drill pipe. Water was then injected into the pipe, creating downward pressure that forced the trapped sediment upward through the pipe. This process was performed carefully to prevent disturbance to the sediment structure and maintain sample integrity. As the sediment emerged from the drill pipe, it was immediately collected in clean containers to ensure sample quality and prevent contamination.

Drilling was conducted at depths ranging from 1 to 15 meters to obtain vertical sediment samples. Each sample was stored in a labeled sample tube containing important information such as the sampling depth code.

RESULTS AND DISCUSSION

The results of this study demonstrate that intact and high-quality vertical sediment samples were successfully obtained. The drilling technique was carried out with careful attention to the environmental conditions at the sampling site.

Accurate positioning of the drilling apparatus in the aquatic environment was achieved using a machine support base, which proved effective in securing high-quality vertical sediment samples. The support base functions as a structural stabilizer that provides mechanical stability to the drilling machine. In the context of physics, this stability is critical for minimizing vibration and positional displacement during the drilling process.

The support base for the drilling machine operating in a lacustrine environment must be engineered to withstand the forces generated by water currents and wave action. Water currents create frictional and oscillatory forces that can potentially cause displacement of the drilling

apparatus. Therefore, the support structure must possess adequate structural strength to resist these forces.

Figure 2. Machine Support Base and Drilling Machine

During the drilling process, vibrations generated by the machine can adversely affect the accuracy and quality of the sediment being drilled. A robust support base helps to dampen these vibrations. In addition, the support base ensures that the drill bit remains properly aligned with the working surface. This vertical alignment is essential for ensuring that the drill penetrates the sediment perpendicularly without lateral deviation, thereby yielding sediment samples that are more accurate and representative of the target stratum.

The sediment drilling process involves several fundamental principles that influence the effectiveness of sample recovery. One critical aspect is the pressure and force applied to the drill. When the machine is in operation, the vertical force exerted must be sufficient to penetrate the sediment layers, yet not so excessive as to disrupt the existing sediment structure.

Figure 3. Vertical Sediment Sample

Furthermore, the use of water pump pressure to expel sediment from the drill pipe, as shown in Figure 3, is an effective method for ensuring that samples remain intact. The hydraulic pressure generated by the pump drives the trapped sediment out of the pipe. As the fluid pressure increases, the resulting upward force lifts the sediment toward the surface. This process leverages Pascal's Law, whereby pressure applied to a confined fluid is transmitted uniformly throughout the fluid, thereby facilitating the ejection of the sediment sample. This method is efficient because it minimizes sample disturbance and allows for cleaner sediment recovery, thus maintaining sample integrity for subsequent analysis.

CONCLUSION

The vertical sediment drilling conducted in this study successfully yielded intact, high-quality samples. This outcome was attributable to the selection of an appropriate drilling position and the effective use of a machine support base. The support base played a critical role in providing stability to the drilling machine, reducing vibration, and maintaining the vertical alignment of the drill bit all of which contributed to the accuracy of sample recovery. The design of the support base must be capable of withstanding forces generated by water currents and wave action; consequently, its

structural strength is of paramount importance. In addition, the controlled application of hydraulic pressure during sample ejection via the water pump proved effective in preserving sample integrity.

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