Application of Next-Generation Sequencing Technology in Southeast Asia: A Practical Framework for Advancing Wildlife Conservation

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Abstract. Next-generation sequencing (NGS) has transformed genomics, presenting significant potential for advancing wildlife conservation. NGS technology offers opportunities and challenges for addressing scientific questions in wildlife management. Unfortunately, there is a lack of comprehensive records on NGS implementation in Southeast Asia, particularly concerning wildlife conservation. To address this gap, we analyzed NGS studies focused on wildlife monitoring in Southeast Asia and introduced a practical framework for implementing NGS technologies in global wildlife conservation, especially in Southeast Asia. We systematically reviewed NGS studies in wildlife monitoring from the SCOPUS database. We identified 137 relevant publications from 11 countries, with Malaysia contributing 36% of the studies. The included studies were categorized into five themes: species identification, dietary assessment, health monitoring, taxonomic resolution, and whole-genome sequencing, with the majority focusing on 38 publications related to wildlife health. The framework developed in this study help the researchers and conservation practitioners with insights on NGS technology application in conservation while also addressing the benefits, limitations, and ethical considerations associated with NGS use. This review offers a brief overview

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of NGS usage and provides guidelines for embracing NGS as a valuable tool for effective wildlife conservation strategies in our rapidly changing world.

1 Introduction

Next-generation sequencing (NGS) technologies, introduced in 2005, have revolutionized biological science after first-generation sequencing or Sanger sequencing was dominant for three decades. NGS successfully broke the limitations of the first generation, especially in the number of samples reads. The advances in sequencing led to large-scale and broad-scope biosystematics projects to be applied for various applications including the Barcode of Life initiative [1]. The emergence of DNA sequencing has led to several commercially available high-throughput sequencing (HTS) platforms based on different chemistries and detection techniques to be used in various fields, including environmental studies. With its high-throughput capacity and cost-effectiveness, the number of studies related to environment scope has been increasing because it can potentially combat many of the challenges associated with biodiversity monitoring [2]. The power of NGS to sequence environmental DNA (eDNA) can lead to overcoming many issues as eDNA is a genetic material of the organism living in the habitat can be found and collected easily [3]. Biodiversity monitoring can be more feasible because the eDNA enables practical detection and classification of species as it can originate from various sources such as skin, mucous, saliva, sperm, secretions, eggs, feces, urine, blood, roots, leaves, fruit, pollen, and decaying remain of larger organisms [4]. Consequently, the acceptance of detecting eDNA can support ex-situ and in-situ conservation by harnessing leading-edge technology in overcome the limitation using the traditional monitoring methods [5, 6].

Additionally, the application of NGS should be widespread, including in Southeast Asia consisting of Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Timor-Leste, and Vietnam [7]. This region is recognized as a global hotspot of biodiversity and endemism [8]. However, it also faces some of the highest deforestation rates, stemming from mining, construction, and human development, which pose a global threat to biodiversity, as reported by Hughes [8]. Hence, the protection and conservation of biodiversity in Southeast Asia is required as some species is now on the verge of extinction. As a powerful tool, NGS can enhance our understanding across various applications, including species identification, health monitoring, dietary assessment, and genomic studies [9,10]. The ability of NGS to trace rare and threatened species across a wide range of taxonomic groups from various habitat and reveal information of entire ecosystems can help to avoid the loss of significant portion especially for endemic species [7, 11,12].

Furthermore, with the development of NGS, this technology can gradually be applied to various taxa, including terrestrial and aquatic populations. Hence, there is a growing need to acknowledge the advantages of NGS which are relevant for the authorities to consider it as part of wildlife monitoring. The efforts can guide for monitoring, importantly caused by the alteration in adapting the surrounding environment from anthropogenic disturbance that affect the host health of wildlife [13,14]. In this study, we aimed to analyze the available research focusing on wildlife monitoring in Southeast Asia using the NGS platform. We also presented an outline of practical NGS-based framework as a standard protocol and include the application in various aspects to provide insight for future wildlife management. Thus, the findings of the study should be further explored especially for Southeast Asia to fill the gaps in understanding the biodiversity loss that will enable more effective and efficient planning to monitor ex-situ and in-situ conservation moving forward. Notably, it is proven that the NGS approach can be applied in conservation management, which provides the