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Popular Article

Role and Application of Molecular Markers: Focus on mtDNA Markers in Aquaculture and Fisheries

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Abstract

Molecular markers have revolutionized the aquaculture field by providing invaluable tools to address critical challenges. They are adept at discriminating between fish species and assessing genetic variations, essential for breeding programs and disease diagnosis. This article focuses on mitochondrial markers in aquaculture and fisheries, providing an overview of their current status and potential applications in the field.

Key words: mtDNA, markers, fisheries, aquaculture

1. Introduction

Over the past three decades, aquaculture production has increased significantly due to advancements in tools and techniques for studying various types of genetic markers across the entire genome of different fish species. However, fish and other seafood have been unsustainably overexploited, leading to population declines. Therefore, molecular-level studies are crucial for rejuvenating wild populations and assessing risks to achieve sustainable aquatic ecosystems. fisheries and aquaculture, and various types of markers have been developed for these purposes. They can be used to select economically important traits for different aquaculture species. Nuclear DNA markers, while valuable for identifying cryptic species, species-level identification, genetic population studies, stock structure analysis, and forensic testing of processed fish products, are economically impractical due to their large size. In contrast, mtDNA markers offer several advantages over nuclear genome markers: they are much shorter in length, highly reproducible, maternally inherited, more conserved, and exhibit high mutation rates due to their rapid replication and lack of proofreading mechanisms. This article highlights the importance of mtDNA markers in aquaculture and fisheries.

1. Principle and types of molecular markers

Polymorphism is a natural occurrence resulting from mutations during DNA replication or due to environmental factors, leading to genetic variation among individuals within a species. These mutations include base substitutions, nucleotide insertions or deletions, DNA segment inversions, rearrangements around specific loci, and translocations between non-homologous chromosomes. Over time, these mutations accumulate and become inheritable, contributing significantly to genetic diversity within populations and providing specific molecular markers that are heritable, measurable, and detectable using specialized methods. Advancements in DNA technologies such as cloning, sequencing, hybridization, and automated sequencing have

Isozymes are enzyme analogs encoded by different forms of alleles at one or more loci, distinguishable by electrophoresis due to differences in their molecular weights. Allozymes, on the other hand, are different forms of enzymes produced by alleles at the same locus but with similar functions. These markers have been pivotal in phylogenetic analyses of fish species like Cyprinids, aiding in studies related to inbreeding, stock identification, parentage analysis, and evolutionary relationships. RFLP markers involve the detection of DNA fragment length variations resulting from digestion with specific restriction enzymes, providing species-specific genetic fingerprints. primers, useful for differentiating geographically and genetically distinct populations and evaluating hybrid vigor in fish species like Guppies. AFLP utilizes selective PCR amplification of DNA fragments generated by restriction enzymes, enabling efficient differentiation between individual strains of species like Ictalurus punctatus and Ictalurus furcatus.

Microsatellites are tandem repeats of DNA sequences distributed throughout the genome, characterized by short repeat units that allow precise differentiation between alleles, making them invaluable for genetic mapping and population studies in fish species. SNPs, resulting from single nucleotide substitutions, insertions, or deletions, provide highly accurate measures of genetic diversity and are widely applicable in studying genetic variations across fish populations. These genetic markers play critical roles in advancing aquaculture practices, conservation efforts, and understanding the evolutionary dynamics of fish populations, contributing to sustainable.

3. Mitochondrial DNA marker and applications in aquaculture and fisheries

A single circular double standard DNA molecule called the mitochondrial genome houses a number of genes. In teleost fishes, the mt-genome can range in size from 16,000 to 19,000 bps. The mitochondrial (mt) genome has more variety in some areas of the genome, indicating a faster rate of evolution.

To explore stock structure in a range of fishes, mtDNA markers have been thoroughly analyzed (Gold et al. 1993). For phylogenetic analysis, the ATPase 6 and 8 subunits, Cytb and CO1 genes are typically employed. Mitochondrial markers frequently use to identify brood stocks (Benzie et al. 2002). One of the major drawbacks of this marker is that, it follows non-mendelian inheritance.

3.1. Inter-specific and intra-specific variations

The use of molecular genetic markers can enhance taxonomy research by assessing genetic divergence. However, rapid divergence in morphological and ecological qualities may result in little association between morphological traits and gene divergence, highlighting the need for more comprehensive and accurate taxonomy research. Molecular markers are crucial for identifying mixed capture species, processed fish products, and early life stages of fish. They are particularly useful when morphological identification is challenging, and can also be used to identify endangered and threatened animals, such as dead and stranded whales and dolphins. Genetic differences within species are more significant than between populations, allowing for identification even with small sample sizes. Molecular markers can also be used to identify intra-specific differences.

3.2. Phylogenetic Study

It is possible to recreate the evolutionary history of several fish species, which will provide crucial data on historical demography. Phylogenetic studies may also be used to extract information about ecological trends and conservation units. Inferring intraspecific phylogenetic patterns from mitochondrial DNA has proven to be a highly effective method for many animal taxa.

3.3 Trophic interaction

Determining the trophic interactions within an ecosystem is the most important aspect of any ecological study, and data on diet composition is particularly important. The majority of the morphological traits may be lost as a result of partial or complete digestion, making it extremely challenging to identify the diet components at the species level. Identification is challenging since the gut sometimes lacks substantial remnants, making it. Since DNA may be extracted from partially digested materials, molecular approaches could be employed for diet analysis research.

4. Conclusion

Advances in molecular techniques have spurred growth in aquaculture, addressing unsustainable exploitation of fish populations. Molecular markers like allozymes, RFLP, RAPD, AFLP, microsatellites, and SNPs play crucial roles in studying genetic variations, identifying traits, and assessing fish population genetics. Mitochondrial DNA (mtDNA) markers, with maternal inheritance and high mutation rates, aid in phylogenetics, genetic diversity studies, and forensic analysis of fish products. Despite limitations, mtDNA markers are powerful tools in aquaculture, enhancing genetic understanding and supporting conservation efforts. Continued development is essential for sustainable aquaculture and biodiversity preservation.

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