**SPATIAL DYNAMICS OF *Melanotaenia arfakensis* COMMUNITY STRUCTURE IN THE API AND ASITI RIVERS: IMPLICATIONS FOR IN SITU CONSERVATION OF ENDEMIC FISHES IN PAPUA, INDONESIA**

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**ABSTRACT**

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| Papua, Indonesia, is home to high freshwater biodiversity, including endemic species such as *Melanotaenia arfakensis*, which is found exclusively in the Kebar highlands. This study aims to analyze fish community structure and the impact of invasive species in two major river systems—Sungai Api and Sungai Asiti—using a spatial approach across upstream, midstream, and downstream segments. The methods employed include ichthyological surveys, measurement of environmental parameters, and ecological indices such as diversity (H'), evenness (E), and dominance (C). Results show that the abundance of *M. arfakensis* drastically decreases from upstream to downstream in both rivers, while invasive species such as *Oreochromis mossambicus* and *Puntius* spp. significantly increase in downstream segments. The highest diversity index was recorded in the downstream section of Sungai Api, though it was accompanied by high dominance of invasive species, indicating ecological disruption. These findings underscore the importance of a zonation-based conservation approach, focusing on upstream habitat protection, midstream ecosystem rehabilitation, and invasive species control downstream. This strategy should be integrated with community participation and ongoing ecological monitoring to support in-situ conservation and the overall preservation of freshwater biodiversity in Papua, Indonesia. |

*Keywords: Melanotaenia arfakensis*, invasive species, river ecosystem, in-situ conservation, Papua

1. INTRODUCTION

Papua, Indonesia, is recognized as one of the world’s global biodiversity hotspots, with its freshwater ecosystems remaining relatively intact. The rivers flowing through the Kebar highlands are natural habitats for a range of fish species, including *Melanotaenia arfakensis*, a rainbowfish species endemic to this region. This species holds high ecological value not only as a unique representative of Papua’s aquatic fauna but also as a key indicator of freshwater ecosystem health (1,2).

However, *M. arfakensis* faces increasing threats to its survival. Habitat fragmentation, land-use changes, elevated sedimentation, and the degradation of riparian vegetation have significantly reduced habitat quality, particularly in the downstream areas (3,4). In addition, the introduction of non-endemic fish species such as *Oreochromis mossambicus* and *Puntius* spp. has intensified ecological pressures on local species through food competition, community structure shifts, and potential hybridization (5,6).

The urgency of this study stems from the lack of comprehensive scientific data regarding the spatial distribution and community structure of *M. arfakensis* in its natural habitat. Previous research has largely focused on taxonomic or descriptive aspects and has yet to explore longitudinal differences in fish community structure from upstream to downstream across endemic regions of West Papua (2,7). Therefore, this study aims to analyze spatial variation in fish community structure, with a focus on *M. arfakensis*, in two key river systems—Api and Asiti Rivers —that represent critical habitats within the Kebar highlands, Papua.

The novelty of this research lies in its spatial approach, which compares fish community structures across upstream, midstream, and downstream segments, while also assessing the impact of introduced species on endemic populations. By analyzing fish abundance and ecological status based on river zonation, this study provides a detailed picture of species dominance patterns and the extent of ecological disturbance driven by anthropogenic activities and non-native species invasions.

The findings of this study are highly significant in the context of in-situ conservation of endemic species in West Papua. The results can serve as a scientific basis for developing zonation-based conservation strategies, habitat restoration programs, and systematic control of invasive species. Additionally, the generated data can support local government, environmental NGOs, and community stakeholders in designing adaptive and sustainable river conservation policies. By emphasizing freshwater biodiversity—often overlooked in national conservation agendas—this study contributes to strengthening ecologically and socially grounded natural resource management in Papua (8,9).

2. material and methods

**2.1 Study Area and Research Design**

This study was conducted in two major rivers located in the Arfak Mountains, Papua, Indonesia —namely the Api and Asiti Rivers—during the period from July to December 2024 (Figure 1). These locations were selected based on the presence of the endemic rainbowfish *Melanotaenia arfakensis*, which is the focus of conservation efforts, and represent diverse ecological conditions of tropical montane river systems. Each river was divided into three ecological segments—upstream, midstream, and downstream—characterized by differences in topography, elevation, and river morphometry.

The segmentation was determined using geomorphological and hydrological approaches, combining digital contour mapping with field surveys to identify elevation changes and river channel structures. The upstream segment is characterized by the highest elevation, steep river gradients, and habitats dominated by fast currents and rocky substrates. The midstream segment serves as a transitional segment with reduced gradient, increasing river depth and width, and more variable substrates. The downstream segment lies at the lowest elevation, with wider channels, slower flow, and dominance of fine sediments. The research design adopted a spatial cross-sectional approach to capture ecological variability along the river continuum, in line with the River Continuum Concept (RCC) (10–12). This was an observational study, with data collection carried out simultaneously across all segments during the dry season to minimize temporal bias caused by seasonal fluctuations.



Figure 1. Research Locations Showing the Segments of Api River and Asiti River, Papua, Indonesia.

**2.2 Data Collection**

A quantitative-descriptive approach was used, employing spatial stratification based on the zonation of river flow: upstream, midstream, and downstream. Each segment represents a gradient of distinct ecological conditions, in terms of river morphometry, riparian vegetation structure, and exposure to external disturbances. The upstream segment generally features dense vegetation cover, rocky substrates, and cooler water temperatures. The midstream segment often experiences channel widening and increased sedimentation, while the downstream segment is more prone to anthropogenic pressures such as farming, land clearing, and domestic waste discharge.

Within each segment, three observation points were selected systematically based on habitat diversity and accessibility. Each observation point covered a 100-meter transect along the river, resulting in nine sampling points per river and a total of 18 across both sites. At each point, environmental data and fish species identification were conducted in situ. This spatial design enabled microhabitat analysis and mapping of optimal conditions for the presence of *M. arfakensis*.

Fish community data were collected using a combination of active and passive sampling methods. Equipment included gill nets (1–2 inch mesh), fish traps (bubu), and small seine nets for shallow waters. Sampling was conducted over 2–4 hours during morning and late afternoon sessions to capture fish activity patterns across diel cycles. Captured fish were anesthetized using MS-222 solution to minimize handling stress during identification. Identification was based on morphological characteristics using the latest taxonomic literature (13–15). The number of individuals per species was recorded, and species status (endemic, native, or introduced) was classified according to distributional data specific to Papua (15,16). Specimens that could not be identified in the field were preserved in 10% formalin for further analysis in the laboratory.

**2.3 Data Analysis**

The number of individuals per species was converted into relative abundance following the ecology indexs (17,18). Fish community structure was further analyzed by calculating several ecological indices, including the Shannon-Wiener Diversity Index (H'), Evenness Index (E), and Simpson’s Dominance Index (D) (18). These indices were computed for each river segment (upstream, midstream, downstream) to reflect variation in biodiversity and community structure, with a specific focus on *M. arfakensis*. Comparisons among segments were analyzed descriptively to identify patterns of species distribution and ecological pressures.

3. results and discussion

**3.1 Community Structure and Ecological Indices**

Analysis of the community structure of aquatic organisms in two river systems, namely Api River and Asiti River, showed significant ecological variation among the upstream, midstream, and downstream segments. The parameters analyzed included abundance (K), species diversity (Shannon-Wiener index, H’), evenness (E), and dominance (Simpson index, C). The data of these indices are summarized in Table 1.

Table 1. Values of Abundance (K), Diversity (H’), Evenness (E), and Dominance (C) in Api River and Asiti River

| **River Location** | **Segment** | **Abundance (K)** | **Diversity (H’)** | **Evenness (E)** | **Dominance (C)** |
| --- | --- | --- | --- | --- | --- |
| Api River | Upstream | 0.095 | 1.297 | 0.590 | 0.619 |
|  | Midstream | 0.032 | 1.428 | 0.797 | 0.694 |
|  | Downstream | 0.043 | 1.665 | 0.801 | 0.762 |
| Asiti River | Upstream | 0.116 | 1.384 | 0.711 | 0.680 |
|  | Midstream | 0.052 | 1.378 | 0.627 | 0.591 |
|  | Downstream | 0.028 | 1.409 | 0.724 | 0.662 |

In general, the highest abundance value was found upstream in the Asiti River (0.116), while the lowest was in the downstream segment of the Asiti River (0.028). This variation reflects changes in primary productivity and ecological pressures along the river flow. The decline in abundance downstream is generally related to habitat quality degradation due to sedimentation, eutrophication, and anthropogenic activities. The highest species diversity (H’) was recorded in the downstream segment of the Api River (1.665), indicating a more complex community structure. This value suggests a relatively stable ecosystem condition (19,20). However, the high dominance value (C = 0.762) in the same segment indicates that community complexity does not necessarily mean an even distribution, as some species may dominate under tolerant conditions to environmental stress (21–23).

The Asiti River showed slight fluctuations in diversity and evenness, but abundance and dominance values indicated degradation from upstream to downstream. These findings are consistent that biotic communities in the downstream segments tend to be more affected by domestic waste and sedimentation, especially in tropical rivers flowing through agricultural or residential areas (21,22).

**3.2. Api River**

Fish distribution in the Api River shows a community structure reflecting interactions among endemic, native, and introduced (alien) species. The endemic species consists of only one type, *M. arfakensis*, while native fish include *Hepaestus lineatus*, *Langusia* sp., and *Neosilurus* sp. The alien fish group is represented by two introduced species, *Puntius binotatus* and *Oreochromis mossambicus*.

In the upstream segment, *M. arfakensis* dominated with 63 individuals (Table 2). As an endemic species found only in the Arfak Mountains region and surroundings, its presence indicates that the upstream area still provides suitable environmental conditions such as clear flow, high oxygen, and rocky substrate characteristic of its habitat. On the other hand, the presence of native species such as *H. lineatus*, *Langusia* sp., and *Neosilurus* sp. is very limited (total 4 individuals) and beginning to be pushed by introduced species such as *Puntius binotatus* (16 individuals) and *O. mossambicus* (1 individual). The introduction of alien species is suspected to originate from local fish farming or aquaculture activities, which then escape into the river.

The midstream segment has a different profile, with 34 individuals of *M. arfakensis* and 22 individuals of native species. Species such as *Langusia* sp. and *Neosilurus* sp. are more common in this section, possibly due to a combination of moderate flow and mixed substrate that suits their ecological preferences. Interestingly, no alien species were found in this segment, indicating that the middle part of the river is relatively protected from external influence or has ecological/flow barriers limiting the invasion of introduced species (24,25).

Downstream, *M. arfakensis* numbered only 22 individuals—the lowest compared to the other two segments. In contrast, native species such as *Hepaestus lineatus*, *Langusia* sp., and *Neosilurus* sp. dominated (31 individuals). However, the most concerning is the increased number of alien species downstream, especially *Puntius binotatus* (10 individuals) and *O. mossambicus* (5 individuals). These species are known as aggressive spreaders with high tolerance to poor water quality and rapid growth, able to compete directly with local species and disrupt ecosystem balance (24). The presence of alien species such as *P. binotatus* and *O. mossambicus* downstream, which increased compared to upstream, indicates active biological invasion. Both species are known as strong competitors and play a role in altering the local community structure (25–27).

Table 2. Number of Fish by Status in Each Segment of Api River

| **River Segment** | **Endemic (*M. arfakensis*)** | **Native (*H. lineatus, Langusia* sp., *Neosilurus* sp.)** | **Alien (*P. binotatus, O. mossambicus*)** |
| --- | --- | --- | --- |
| Upstream | 63 | 4 | 17 |
| Midstream | 34 | 22 | 0 |
| Downstream | 22 | 31 | 15 |

**3.3. Asiti River**

Asiti River, flowing through Papua, is one of the freshwater systems rich in biodiversity, both in species uniqueness and ecological pressure faced. The fish composition in three main segments—upstream, midstream, and downstream—provides an important overview of species distribution based on status: endemic, native, and alien. This data is relevant not only for ecosystem management but also for regional conservation policy formulation.

From a total of 279 recorded fish individuals, conservation status and species origin are important factors in assessing the river ecosystem health. The endemic species found is *M. arfakensis*, one of the characteristic Papua rainbowfishes. This species dominated in the upstream and midstream segments, with 64 and 55 individuals respectively. However, a drastic decline is observed downstream, where only two *M. arfakensis* individuals were recorded. This pattern is consistent with findings stating that Papua rainbowfish species are highly dependent on stable, high-quality environmental conditions and very sensitive to habitat changes (28–32).

Meanwhile, native fish such as *Neosilurus* sp., *Langusia* sp., *Rhinogobius similis*, *Bostrychus* sp., and *Hepaestus lineatus* showed a more balanced distribution. In the midstream segment, native species numbered 30 individuals, the highest compared to other segments. This condition indicates that the midstream area still maintains natural habitat characteristics that support local species sustainability. In upstream and downstream, individuals of this group reached only 13 each. Studies by (33) reinforce that native species highly depend on natural river structure and stable flow but remain vulnerable to physical disturbances and competition.

Most striking in this analysis is the increasing dominance of alien species, especially downstream. The number of alien fish individuals downstream reached 42, consisting of *Puntius* sp., *Oreochromis mossambicus*, and *Channa striata*. Upstream, the number was even higher at 56 individuals. These types are known to be broadly adaptive and tend to be invasive. *Puntius binotatus* and *O. mossambicus*, for example, are known to have highly competitive impacts on native and endemic fish. This aligns with (25), which stated that the presence of tilapia and common carp often leads to a decrease in local species diversity through food competition, habitat alteration, and predation pressure.

Midstream is the only area showing better ecological balance. In addition to the dominance of *M. arfakensis*, native fish communities are more abundant and alien fish are almost absent. Only four individuals from alien groups were identified in this segment. This condition highlights the importance of the midstream as an ecological buffer segment relatively protected from invasion pressure. (24) emphasize that such segments are critical for maintaining local community stability and are priority targets for protection.

Distribution by river segments, summarized in Table 3, reinforces the above narrative. The presence of endemic species sharply decreases from upstream to downstream. Conversely, alien species significantly increase, especially in the downstream area more affected by human activities. Native fish communities remain relatively stable in the midstream, indicating the existence of ecological space that supports local diversity. The presence of *O. mossambicus*, *Clarias* sp., and *Puntius* sp. downstream further confirms the ecological pressure occurring. Studies by (7) state that these alien species have high reproductive capabilities and can ecologically and tropically displace local fish.

Table 3. Number of Fish by Status in Each Segment of Asiti River

| **River Segment** | **Endemic (*M. arfakensis*)** | **Native (local species)** | **Alien (introduced species)** |
| --- | --- | --- | --- |
| Upstream | 64 | 13 | 56 |
| Midstream | 55 | 30 | 4 |
| Downstream | 2 | 13 | 42 |

**3.4 Comparative Synthesis of Fish Community Structure**

A comparative analysis between Api River and Asiti River reveals significant differences and similarities in fish community structure influenced by the spatial segmentation of the rivers (upstream, midstream, and downstream), as well as ecological interactions among native, endemic, and alien species. Both rivers show common trends such as a decrease in endemic species abundance from upstream to downstream, an increase in the presence of alien species in downstream segments, and fluctuations in ecological indices such as diversity (H'), evenness (E), and dominance (C).

In the upstream segments, both Api and Asiti Rivers exhibit the highest abundance and proportion of endemic species *M. arfakensis*, with 63 individuals (0.0537) and 64 individuals (0.056) respectively. This indicates that the upstream segments of both rivers remain important habitats for endemic species, with relatively stable ecological conditions and low disturbance levels. These findings, showing that *M. arfakensis* is highly dependent on good habitat quality, natural substrates, and undisturbed riparian vegetation (7).

In the midstream segments, a shift in community composition occurs. In Api River, *M. arfakensis* decreases to 34 individuals, while native species such as *Langusia* sp. and *Neosilurus* sp. begin to play a more significant role. Meanwhile, Asiti River records an increase in species number (9 species) and a higher proportion of native species, indicating potential conservation areas with relatively low anthropogenic pressure. This phenomenon is associated with heterogeneous habitat conditions, moderate flow, and mixed substrates, which ecologically support the local fish communities (34).

In the downstream segments, both rivers experience a sharp decline in the number of *M. arfakensis* individuals (22 and 2 individuals respectively), along with increased dominance of alien species, especially *O. mossambicus* and *Puntius* sp. Specifically, in Asiti River, alien species dominate the downstream community with 30 individuals of the genus *Puntius*. This indicates high ecological pressure due to biological invasions, habitat quality degradation, and human activities such as agriculture and settlements (35,36). The dominance index (C) in the downstream segments of both rivers is high (0.762 in Api and 0.662 in Asiti), reflecting the strong influence of dominant species that reduce ecosystem balance (37).

Based on the Shannon-Wiener diversity index (H'), the downstream segment of Api River actually has the highest value (1.665), followed by the downstream segment of Asiti River (1.409). These values do not necessarily indicate better ecosystem quality but may suggest an increase in opportunistic or pollution-tolerant species, as noted by Das et al., (2013). Evenness (E) in both rivers tends to increase towards downstream, but this is not accompanied by improved ecological quality due to simultaneous increased dominance of one or two species (39).

In synthesis, Api River reflects a more stable community dynamic in the midstream and downstream, despite increasing dominance. In contrast, Asiti River shows sharper community degradation downstream with increasing invasive species. Environmental factors such as water quality, substrate, riparian vegetation, and anthropogenic pressure are key determinants of community structure, as emphasized by (40). Based on the analysis of fish community structure in Api and Asiti Rivers, the most effective conservation approach is to implement spatially zoned management. This is because each river segment—upstream, midstream, and downstream—shows distinct ecological characteristics and environmental pressures, requiring tailored conservation strategies.

In the upstream segments of both rivers, the relatively high presence of endemic species such as *M. arfakensis* indicates that habitats here are still relatively intact and support the survival of vulnerable species. Therefore, strict protection of the upstream segments is necessary. This protection should include controlling human activities that potentially damage habitats, such as illegal logging, water pollution, and changes to river flow. Conservation efforts in the upstream area should focus on maintaining water quality, preserving riparian vegetation, and minimizing physical disturbances to the river substrate to keep natural habitats intact.

Meanwhile, the midstream segments, which show relatively high species diversity and the presence of native species, are key to maintaining overall fish community stability. Here, ecosystem rehabilitation is important to restore ecological functions that have begun to decline due to mild to moderate anthropogenic pressures. Rehabilitation can include planting riparian vegetation to reduce erosion and sedimentation, managing domestic and agricultural waste to prevent river pollution, and regulating land use around the river to avoid disturbing fish habitats. This approach not only maintains native fish diversity but also strengthens ecosystem resilience against external disturbances.

In the downstream segments, the biggest challenge is the invasion and dominance of alien species such as *O.* *mossambicus* and *Puntius* sp., which can displace native fish communities and reduce overall ecosystem quality. Therefore, controlling alien species populations is a crucial aspect of downstream river management. Control strategies may include reducing alien fish populations through fisheries management, preventing the introduction of new invasive species, and habitat restoration to improve environmental conditions, giving native species a better chance to survive. Additionally, education and involvement of local communities are critical to raising awareness about the importance of biodiversity conservation and reducing activities that accelerate the spread of alien species. Community participation can strengthen conservation efforts through monitoring, reporting, and behavior changes in river resource management.

This zonation approach aligns well with the principles of Watershed-Based Management, emphasizing integrated and holistic management of entire river ecosystems and their environments. By applying different management strategies for each segment according to its characteristics, conservation efforts can be more efficient and effective in sustaining fish resources and the overall river ecosystem. Such approaches have proven successful in various tropical ecosystems, where protecting critical habitats and spatially managing anthropogenic pressures have significant positive impacts on biodiversity conservation and ecological function of rivers (4).

**3.5. Insitu Conservation Implications**

The results of the study in Api River and Asiti River show a significant decline in the population of *M. arfakensis* from upstream to downstream, which ecologically serves as an important indicator of habitat degradation along the river flow. *M. arfakensis* is an endemic species that heavily depends on specific habitat conditions such as sandy substrates, moderate current, and high dissolved oxygen levels. The presence and abundance of this species are inversely correlated with the increasing dominance of alien species like *O. mossambicus*, which tolerate environmental changes caused by human activities, such as sedimentation and eutrophication from agricultural lands and settlements (41).

The analysis of fish community structure and diversity indices applied in this study provides a comprehensive overview of the ecological condition of the rivers. The decreasing Shannon-Wiener diversity index from upstream to downstream indicates increasing ecological pressure downstream, resulting in a decline in the number and variety of native fish species (42,43). Meanwhile, the increasing dominance index downstream reflects the dominance of invasive alien species that threaten ecosystem balance and the survival of native species (42).

The in situ conservation implications arising from these findings call for management approaches focused on protecting natural habitats and reducing ecological disturbances throughout the river segments. First, riparian vegetation rehabilitation in the upstream and midstream sections is crucial to restore ecological functions, maintain water quality, and provide habitat that supports endemic species sensitive to environmental changes. Healthy riparian vegetation helps reduce sedimentation and improve substrate quality needed by *M. arfakensis* and other native fish (42,44).

Second, controlling alien species must be a priority, especially in the downstream sections, where the dominance of *O. mossambicus* and other invasive species is already very high. This effort can be conducted through strict fisheries regulation, habitat monitoring, and managing alien fish populations to prevent damage to native fish communities. This is important because invasive species not only compete directly with native fish but can also alter community structure and overall ecosystem functions (6).

Third, in situ conservation cannot be effective without the involvement of local communities. Education and active community participation in monitoring and managing the rivers can strengthen supervision of activities that damage habitats and encourage sustainable fishery management practices. Community-based conservation approaches have proven to improve the success of natural resource protection while maintaining social and economic balance in local societies.

Finally, long-term biological monitoring using ecological indicators such as diversity and dominance indices is essential to assess the effectiveness of conservation actions and to detect early changes in fish communities. Monitoring data can be used to adapt management strategies to remain responsive to ecosystem dynamics. By integrating these aspects into in situ conservation strategies, it is expected that the preservation of Papua’s endemic fish diversity, such as *M. arfakensis*, can be maintained while sustaining the ecological functions and balance of river habitats in a sustainable manner.

4. Conclusion

The comparative study of fish community structures in the Api and Asiti Rivers, Papua, Indonesia reveals significant spatial variations influenced by ecological factors and anthropogenic pressures across upstream, midstream, and downstream segments. The endemic species *M. arfakensis* dominates upstream areas, highlighting the importance of preserving these relatively stable habitats. In contrast, downstream segments experience increased invasion and dominance by non-native species such as *O. mossambicus* and *Puntius* spp., driven by habitat degradation and human activities. Biodiversity indices indicate declining native species diversity and increasing ecological stress toward the downstream segments.

These findings underscore the critical need for spatially segmentd, in situ conservation strategies focused on habitat protection, invasive species control, and ecosystem rehabilitation. Riparian vegetation restoration and strict management of anthropogenic disturbances are vital in upstream and midstream areas to support endemic species and maintain ecological functions. Downstream conservation efforts must prioritize controlling invasive populations and restoring habitat quality to prevent further biodiversity loss. Furthermore, active local community involvement and continuous ecological monitoring are essential for adaptive management and long-term sustainability. Implementing integrated watershed-based management that considers segment-specific ecological characteristics will enhance conservation effectiveness, safeguard endemic fish diversity, and preserve the ecological integrity of these riverine systems in Papua.

Consent (where ever applicable)

Not applicable. this study did not involve human participants or patient data.

Ethical approval (where ever applicable)

Not applicable. This study did not involve any human participants or experimental animals.

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