

# Utilization of Biological Control Agents *Neochetina* spp. Beetles in Control of Water Hyacinth (*Eichhornia crassipes* (Mart.) Solms) in Lake Tondano, Minahasa Regency, Indonesia

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## ABSTRACT

Lake Tondano, located in Minahasa Regency, North Sulawesi Province, holds strategic ecological, economic, and socio-cultural importance, but is currently facing a serious threat from the invasion of water hyacinth (*Eichhornia crassipes* (Mart.) Solms). As an environmentally friendly alternative to mechanical or chemical control, the use of biological control agents has become an increasingly attractive option. One biological control agent proven effective against water hyacinth is the *Neochetina* spp. weevil, consisting of *Neochetina eichhorniae* and *Neochetina bruchi*. These beetles are highly host-specific and attack water hyacinth during both larval and adult stages. This study aimed to evaluate the destructive ability of *Neochetina* spp. as biological control agents on water hyacinth growth in Lake Tondano. The experiment was conducted in the field using a Randomized Block Design (RBD) with five treatments and three replications. The treatments consisted of 0, 10, 30, 60, and 90 adult beetles released onto 100 water hyacinth plants. Results showed that feeding scar on leaves increased consistently from Observation 1 to Observation 3, and the severity of damage was directly influenced by the number of adult beetles released. In

Observation 1, damage ranged from 5.66 (P1) to 39.33 (P5), while in Observation 2 it increased from 2.0 (P1) to 2658.66 (P5), and in Observation 3 from 11.0 (P1) to 2937.66 (P5). Similar patterns were observed for leaf scraping damage, which also increased with beetle density. Furthermore, water hyacinth biomass decreased significantly as the number of *Neochetina* spp. adults increased. This reduction resulted from tissue damage by adults, internal feeding by larvae, and subsequent physiological stress on the plant. Overall, the decline in biomass demonstrates the potential of *Neochetina* spp. as effective biological control agents and supports their role in promoting healthier aquatic ecosystems.

**Keywords:** *Neochetina* spp, *Eichhornia crassipes*, feeding scar, biomass.

## INTRODUCTION

Tondano Lake, located in Minahasa Regency, North Sulawesi, Indonesia, plays a strategic role ecologically, economically, and socio-culturally. It serves as a source of livelihood for local communities, clean water, irrigation, electricity generation, and tourism. However, the Lake Tondano ecosystem faces a serious threat from the invasion of the aquatic weed water hyacinth (*Eichhornia crassipes* (Mart.) Solms). The

uncontrolled invasion and growth of water hyacinth have led to water area narrowing, water quality degradation, biodiversity loss, and disruption to community economic activities (Karouw & Soeryanto, 2024).

Water hyacinth is known as one of the most invasive aquatic weeds in the world. Its rapid growth rate allows it to quickly cover the water surface, reducing sunlight penetration and inhibiting photosynthesis by other aquatic organisms. Water hyacinth control efforts often rely on mechanical or chemical methods. However, these approaches have limitations, such as high costs, environmental side effects, and negative impacts on non-target organisms (Sutrisno & Wibowo, 2024).

As a more environmentally friendly alternative, the use of biological control agents (APH) offers a promising solution. One biological control agent (APH) that has proven effective is the *Neochetina* spp. beetle, comprising *Neochetina eichhorniae* and *Neochetina bruchi*. This beetle specifically attacks water hyacinth, both in its larval and adult stages. The beetle's feeding activity can reduce the growth rate of water hyacinth and suppress its spread, thereby helping restore the balance of the aquatic ecosystem (Sapdi et al., 2016; Tooy, 2024).

Research on the use of *Neochetina* spp. beetles as biological control agents for water hyacinth in Lake Tondano is still limited, despite its enormous potential. Therefore, this study aims to explore the effectiveness of *Neochetina* spp. beetles in controlling the water hyacinth population in Lake Tondano, while simultaneously encouraging the implementation of biological control as part of the integrated management of the lake ecosystem. It is hoped that this research can make a real contribution to the conservation of Lake Tondano and improve the welfare of the surrounding community.

## MATERIALS & METHODS

### Time, Place and Materials

This research was conducted from March to September 2025. This research was conducted in the Field Laboratory in Tonsaru Village, South Tondano District, Minahasa Regency, North Sulawesi Province, Indonesia. The materials used are *Neochetina* spp. beetles (*N. bruchi* and *N. crassipes*), water hyacinth plants *Eichhornia crassipes* (Mart.) Solms (leaves, petiole stems, stem bases, and roots, tissue, cotton, bamboo stems, plastic ram dividers, string and water. While the tools used are, rope, knife, boat, plastic container, handcounter, drying machine, scales, tweezers, brushes, stationery, brushes, microscopes, cameras/cell phones, and altimeter application.

### Research Methods

The research was conducted as an experiment using a Completely Randomized Design (CRD) consisting of 5 treatments and 3 replications. The treatments used were 0, 10, 30, 60, and 90 test beetles, resulting in a total of 570 test beetles. The treatments were as follows:

P1 = 0 *Neochetina* spp. adults with 100 clumps of water hyacinth.

P2 = 10 *Neochetina* spp. adults with 100 clumps of water hyacinth.

P3 = 30 *Neochetina* spp. adults with 100 clumps of water hyacinth.

P4 = 60 *Neochetina* spp. adults with 100 clumps of water hyacinth.

P5 = 90 *Neochetina* spp. adults with 100 clumps of water hyacinth.

For each treatment, a 1 m x 1 m experimental area was required and filled with 100 clumps of water hyacinth plants, so the number of clumps required was 5 treatments multiplied by 3 replications multiplied by 100 clumps of water hyacinth plants, resulting in a total of 1,500 clumps of water hyacinth plants. The clumps of water hyacinth plants that were the objects of observation were 30-50 cm high.

The research implementation started from the preparation of *Neochetina* spp. beetles,

preparation of water hyacinth plants, and application of *Neochetina* spp. beetles. Observation parameters were (1) Number of feeding scar on 10 leaves by *Neochetina* spp.; (2) Number of feeding scar on petioles (leaf base) (number of petiole samples per treatment according to replication is 10 petioles); (3) Calculation of biomass of water hyacinth plants that had not been attacked and after being attacked by beetles in the first month of observation (second week), second observation (sixth week), and third observation (10th week).

### STATISTICAL ANALYSIS

The data were statistically tested using Analysis of Variance, using the SPSS version 27 application program and

continued with the Least Significant Difference Test (LSD) at the 5% (0.05) level.

### RESULT AND DISCUSSION

#### Damage Caused by *Neochetina* spp. on Water Hyacinth Leaves

Based on the results of observations on water hyacinth leaf damage caused by *Neochetina* spp. beetles, it shows that all treatments can be attacked by beetles so that between treatments shows significant differences. Analysis of variance on the average number of infestations by *Neochetina* spp. on water hyacinth plant leaves according to observations can be seen in Table 1.

**Table 1. Analysis of Variance of the Average Number of Plants by *Neochetina* spp. on Water Hyacinth Leaves According to Treatment in Observations 1, 2, and 3.**

Treatment	Average Number of Feeding Scar on Leaves by <i>Neochetina</i> spp.		
	Observation 1	Observation 2	Observation 3
P1 = 0 <i>Neochetina</i> spp.	5,66*a	10,66*a	11, 0*a
P2 =10 <i>Neochetina</i> spp.	399,33b	511,66b	593, 33b
P3 = 30 <i>Neochetina</i> spp.	391,0c	1233,33c	1569,0c
P4 = 60 <i>Neochetina</i> spp.	1458,0d	1966,0d	2174, 0d
P5 = 90 <i>Neochetina</i> spp.	2048,66e	2658,66e	2937,66e

\*) Numbers followed by the same letter indicate no significant difference.

Table 1 shows that the results of the analysis of variance (ANOVA) on the average number of feeding scar caused by *Neochetina* spp. on water hyacinth leaves indicate that different beetle treatments significantly affected damage intensity throughout the observation period. Increasing the number of *Neochetina* spp. individuals released (Treatments P1-P5) was consistently followed by an increase in the amount of damage to water hyacinth leaves. This is evident from the significant differences between treatments, indicated by different letter notations in Table 1.

In the first observation, the treatment without beetles (P1) only resulted in an average of 5.66 feeding scars. This was due to the treatment layout in the field being limited by the beetles' flight ability, allowing them to move to the control treatment P1. Meanwhile, the release of 90

*Neochetina* spp. individuals (P5) resulted in the highest amount of feeding scar (2048.66). This pattern was consistent in the second and third observations, with P5 consistently showing the highest level of defoliation, followed sequentially by P4, P3, and P2. The very significant increase in feeding scar numbers from P3 to P5 indicates that the feeding activity of *Neochetina* beetles increased along with the increase in population and adaptation time on the target plants.

This phenomenon aligns with the biological characteristics of *Neochetina eichhorniae* and *Neochetina bruchi*, known as effective biological agents for controlling water hyacinth. Both species feed by scratching leaf tissue, triggering the formation of necrotic spots that reduce the plant's photosynthetic capacity (Center & Hill, 2002). The high number of feeding scars in

treatments P4 and P5 indicates that larger beetle populations accelerate leaf tissue damage, which ultimately has the potential to inhibit water hyacinth vegetative growth. The results of this study are consistent with previous findings showing that large releases of *Neochetina* can significantly reduce water hyacinth biomass. Julien et al. (2001) reported that dense *Neochetina* populations can increase defoliation intensity by 10–20 times compared to low populations, which subsequently reduces the growth rate and regeneration capacity of this aquatic weed. Furthermore, according to Gutiérrez et al. (1998), the level of leaf damage is an important indicator of the success of biological control because it is directly related to the reduction in energy reserves and photosynthetic capacity of plants. The increase in the number of plants from the first to the third observation in each treatment (except P1) indicates an adaptation process and increased feeding activity over time. At the initial release, the beetles needed time to settle and begin intensive feeding, but in subsequent observations, feeding activity increased

significantly. This is consistent with the report of Heard & Winterton (2000) that *Neochetina* typically exhibits higher feeding rates after an adaptation period of 3–7 days. Overall, the results of this study indicate that the higher the number of *Neochetina* released, the greater the damage to water hyacinth leaves. Therefore, releasing larger beetle populations can be recommended as a more effective biological control approach. However, determining the optimal release rate requires consideration of aquatic environmental conditions and potential interactions with local organisms.

### Damage by *Neochetina* spp. on Water Hyacinth Petioles

Based on the results of observations on the damage to the petioles of water hyacinth plants due to feeding scar by *Neochetina* spp. beetles, it shows that all treatments can be attacked by beetles so that between treatments shows a significant difference. Analysis of variance on the average number of attacks by *Neochetina* spp. on the petioles of water hyacinth plants according to observations can be seen in Table 2.

**Table 2. Analysis of Variance of the Average Number of Damages by *Neochetina* spp. on Water Hyacinth Petioles According to Treatment in Observations 1, 2, and 3**

Treatment	Average Number of Damages to Leaves by <i>Neochetina</i> spp.		
	Observation 1	Observation 2	Observation 3
P1 = 0 <i>Neochetina</i> spp.	5,66 <sup>*a</sup>	2,0 <sup>*a</sup>	3,0 <sup>*a</sup>
P1 = 10 <i>Neochetina</i> spp.	6,33 <sup>ab</sup>	13,0 <sup>b</sup>	14,66 <sup>b</sup>
P1 = 30 <i>Neochetina</i> spp.	6,33 <sup>bc</sup>	22,66 <sup>c</sup>	22,33 <sup>c</sup>
P1 = 60 <i>Neochetina</i> spp.	24,0 <sup>c</sup>	24,0 <sup>d</sup>	37,66 <sup>d</sup>
P1 = 90 <i>Neochetina</i> spp.	39,33 <sup>d</sup>	29,33 <sup>d</sup>	39,33 <sup>d</sup>

\*) Numbers followed by the same letter indicate no significant difference.

Based on Table 2, the analysis of variance shows that the amount of damage to the petioles (leaf stalk tips) of water hyacinth increased significantly with the increase in the number of *Neochetina* spp. beetles, as indicated in each treatment. In the treatment without *Neochetina* spp. (P1 = 0), damage was very low throughout the observation period. Conversely, the addition of 10 to 90 *Neochetina* spp. individuals per plant resulted in increasingly high levels of damage (feeding scars). This is indicated by

the difference in the letter values in the follow-up test results, indicating a significant difference between treatments. This increase in damage indicates that the number of *Neochetina* spp. is strongly related to the intensity of damage to plant petioles. At the initial observation, the intensity of the damage was still relatively low, but with increasing time and beetle feeding activity, the amount of damage increased dramatically, especially in the treatments with 60 and 90 individuals. This

aligns with the biological characteristics of *Neochetina* spp., where adults chew on the surface of the petiole, while larvae bore into internal tissues, causing structural damage that worsens the condition of the water hyacinth plant.

Petiole damage has important ecological significance. Petioles are leaf support structures that play a role in photosynthesis, nutrient transport, and plant buoyancy. When petioles are damaged, the vascular tissue is disrupted, which can result in: decreased plant mechanical strength, torn leaves and broken stems, impaired photosynthesis, and reduced growth and regeneration capacity. According to Center & Van (1994), petiole damage is the most important form of attack because it directly contributes to reduced water hyacinth buoyancy, making plant populations more susceptible to sinking or rot. This is consistent with research by Sapdi et al. (2004) that found that *Neochetina* larval activity on petioles can reduce water hyacinth's ability to maintain turgor, thereby slowing growth and accelerating plant mass degradation. Therefore, the data from this study, which shows increased gardening on petioles, strongly indicates that *Neochetina* spp. are effective as biocontrol agents.

In treatments with 10–30 *Neochetina* beetles per plant unit, the number of gardening occurs gradually. During this phase, the plant is still able to physiologically compensate by forming new leaves. However, at densities of 60–90 individuals, infestation increases sharply and attacks the entire petiole surface, reducing the plant's compensatory capacity and disrupting growth. Furthermore, Buchanan (2019) reported that heavy infestation of petioles can trigger a local plant immune response, but when damage exceeds a certain threshold, this response is no longer effective, and the plant suffers permanent structural damage.

The results of this study showed a similar pattern, with petiole damage increasing significantly from the first to the third observation in treatments with 60–90

individuals, indicating that the plant's regeneration capacity had been exceeded. These results align with Borkakati et al. (2025), who reported that *Neochetina eichhorniae* and *N. bruchi* can cause severe petiole damage, resulting in reduced buoyancy and leaf degradation. Furthermore, Mukarugwiro (2023) stated that the success of *Neochetina* spp. is strongly influenced by population density, with increasing adult numbers directly correlated with increased petiole damage. Van & Center (2002) found that *Neochetina* beetle feeding on petioles can reduce effective leaf area by more than 60%, resulting in decreased water hyacinth growth. Furthermore, Sapdi et al. (2004) demonstrated that petiole damage accelerates plant death due to disruption of nutrient and water transport within the tissue.

The results of this study, which also showed that the highest increase in gardening was in the 90-individual treatment (P5), support all the literature and emphasize that *Neochetina* is effective in inhibiting water hyacinth growth through the mechanism of petiole damage. Based on the research data, it provides a clear picture that the use of *Neochetina* spp. beetles in large numbers results in higher control effectiveness. At the field scale, mass release of beetles can help reduce the coverage of water hyacinth plants, especially in inundated areas that are difficult to reach with physical or chemical methods. However, previous studies also emphasize that long-term success requires integration with environmental factors such as water quality, the presence of natural predators, and the initial density of water hyacinth.

### **Calculation of Water Hyacinth Plant Biomass Due to Damage by *Neochetina* spp.**

Based on the results of weighing the wet weight biomass, dry weight and observation time and the percentage of dry weight reduction have been carried out according to the treatment and observation time. The

biomass of water hyacinth attacked by *Neochetina* spp. according to treatments P1-P5 can be seen in Table 3.

**Table 3. Biomass of Water Hyacinth attacked by *Neochetina* spp. according to Treatments P1-P5 in Observations 1, 2 and 3.**

Treatment	Water Hyacinth Biomass without Roots according to Observations (Gram/plant)								
	Observation 1			Observation 2			Observation 3		
	Fresh Weight	Dry Weight	%	Fresh Weight	Dry Weight	%	Fresh Weight	Dry Weight	%
P1 (0 Imago/100 plants)	987.2	108.3	10.9	955.3	118.7	12.4	992.4	105.7	10.6
P2 (10 Imago/100 plants)	876.5	53.6	6.1	765.3	36.4	4.7	677.1	34.5	5.0
P3 (30 Imago/100 plants)	744.3	47.3	6.3	653.8	25.3	3.8	568.4	18.6	3.2
P4 (60 Imago/100 plants)	682.1	41.5	6.0	478.4	19.6	4.0	423.4	15.2	3.5
P5 (90 Imago/100 plants)	577.4	32.3	5.5	435.6	14.2	3.2	392.6	12.3	3.1

Based on the data in Table 3, it can be seen that the biomass of rootless water hyacinth (wet and dry weight) in treatments P2–P5 decreased significantly compared to P1 (without adults). The decrease in biomass increased as the number of *Neochetina* spp. adults increased from 10 to 90 per 100 water hyacinths.

Data from the control treatment (P1 – 0 adults) showed that water hyacinth biomass

remained stable across all three observations: wet weight ± 955–992 g, dry weight ± 105–118 g, and dry matter percentage ± 10–12%. These results indicate that water hyacinth was in normal physiological condition without herbivore stress. When treated with *Neochetina* spp. (P2–P5), the higher the number of adults, the greater the decrease in biomass, as shown in Table 4.

**Table 4. Fresh Weight, Dry Weight, and Percentage of Dry Weight Loss**

Treatment	Decreasing Fresh Weight (P1-P5)	Decreasing Dry Weight P1-P5	Percent of Decreasing Dry Weight
P1 → P2	987 g → 876 g	108 g → 53 g	10.9 → 6.1
P1 → P3	987 g → 744 g	108 g → 47 g	10.9 → 6.3
P1 → P4	987 g → 682 g	108 g → 41 g	10.9 → 6.0
P1 → P5	987 g → 577 g	108 g → 32 g	10.9 → 5.5

Based on Table 4. above, in the third observation, the pattern of decline is increasingly clear where Treatment P5 (90 imago) showed a biomass of only ± 392–577 g wet and ± 12–32 g dry, much lower than the control. This indicates that herbivory attacks cause tissue damage, decreased photosynthetic area, and decreased biomass reserves. The results of this study are in accordance with the biological mechanism of *Neochetina* spp. which has been reported that adult insects/imago can damage the surface of leaves and petioles (leaf stalks) so that

imago attacks cause: bite wounds in the form of scratched tissue or feeding scars, causing damage to epidermal tissue, and decreased photosynthetic capacity. Recent studies have shown that imago attacks cause ~30–70% loss of photosynthetic area, depending on population density (Borkakati et al., 2025). It is further explained that the larvae that hatch from eggs laid in the petiole bore into the spongy tissue (aerenchyma), causing damage to the transport tissue, disruption of water and nutrient transport, and a decrease in turgor and fresh weight. According to

Mukarugwiro et al. (2023) that internal damage by larvae is the main factor in the decline in water hyacinth biomass. In addition, the decrease in total biomass due to physiological stress in which the combination of external wounds + internal wounds causes plants to experience oxidative stress, decreased photosynthesis rate, increased respiration, and disrupted growth, which ultimately leads to a decrease in fresh and dry weight. The results of this study are in line with the research of Center & Van (1994) that *Neochetina* spp. beetle attacks can reduce water hyacinth biomass by up to 70% in 6–8 weeks under intensive conditions.

There is a relationship between the number of imagoes and the level of biomass decline. Table 3 shows a decreasing linear relationship: the greater the number of imagoes, the greater the biomass decline. At a density of 90 imagoes, biomass decreased by more than 50% compared to the control. These results are consistent with the findings of Julien et al. (2001), who reported that increasing *Neochetina* populations were highly correlated with a decrease in water hyacinth biomass during a control program in Lake Victoria. Gutiérrez et al. (2021) confirmed that a beetle population of at least 30–50 individuals per square meter is required to have a significant effect on water hyacinth biomass.

Ecological implications and weed control implications include decreased biomass slows the spread of water hyacinth. Low biomass can lead to decreased stolon production, slowed vegetative reproduction, decreased buoyancy, and accelerated leaf yellowing. The effectiveness of biological control increases at high imago densities, with P5 (90 imagoes) the treatment with the best control results. These results support the integrated biocontrol model described by Winston et al. (2023), which states that successful control depends on adequate weevil populations and supportive water conditions.

## CONCLUSION

1. Feeding scars on water hyacinth leaves increased from observations 1 to 3. The number of feeding scars on leaves, according to observations, was largely determined by the number of adult beetles according to treatment. In observation 1, treatment P1 was the lowest (5.66) and treatment P5 was the highest (39.33). In observation 2, the lowest was P1 (2.0) and treatment P5 was the highest (2658.66). In observation 3, the lowest number of feeding scars was P1 (11.0) and treatment P5 was the highest (2937.66).
2. Feeding scars on water hyacinth petioles occurred from observations 1 to 3. The number of feeding scars on leaves, according to observations, was largely determined by the number of adult beetles according to treatment. In observation 1, treatment P1 was the lowest (5.66) and treatment P5 was the highest (2048.66). In observation 2, the lowest was P1 (10.66) and treatment P5 was the highest (29.33). In observation 3, the lowest number of feeding scars was in P1 (3.0) and the highest in P5 (39.33).
3. Water hyacinth biomass decreased significantly as the number of *Neochetina* spp. imago beetles increased. This decrease was caused by damage to leaf tissue and petioles by imagoes and movement of internal tissues by larvae. This decrease in biomass has a positive impact on biological control efforts and aquatic ecosystem health.

### *Declaration by Authors*

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