

# *Perna viridis* as a coastal sentinel for hydrology and education: a reflective and conceptual synthesis

## Abstract

This article integrates over two decades of ecological research on the green-lipped mussel *Perna viridis* with reflective insights to explore its significance as both a biological sentinel and an educational model. Since 1998, studies have documented its biology, ecology, and capacity for bioaccumulating pollutants, highlighting its role in coastal hydrological monitoring. The manuscript frames these findings within a reflective conceptual approach, using the FIKR (Facets, Insights, Knowledge, Resilience) framework to draw parallels between the mussels' resilience and human adaptation. This integration of science and reflection underscores how long-term species-specific research can inform environmental monitoring, invasive species management, and science education. By linking ecological facts with personal narrative, the article offers a multidimensional perspective for advancing environmental literacy and adaptive management in coastal hydrology.

**Keywords:** *Perna viridis*, resilience, invasive species, science communication, environmental psychology, ecological reflection

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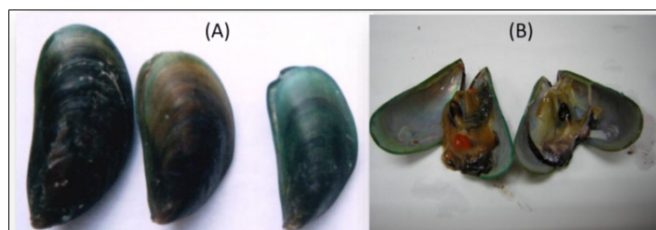
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## Introduction

### A journey that never left me in 1998

I began studying the green-lipped mussel *Perna viridis* (locally known as *kupang*) (Figure 1) in 1998 as a young lecturer (Figure 2A) and postgraduate researcher (Figure 2B) who was curious, uncertain, and new to the world of marine ecology. I had little understanding of what this unassuming bivalve could teach me. Over the subsequent decades, that initial uncertainty transformed into a life's work marked by dozens of publications spanning the mussel's biology, ecology, and ecotoxicology.<sup>1</sup> On 22 June 2025, a Scopus database search for "*Perna viridis*" in article titles revealed that I topped the list of contributing authors worldwide with 52 publications – a niche scholarly achievement that, jokingly, might earn me a "Gold Medal" in the *P. viridis* hall of fame.

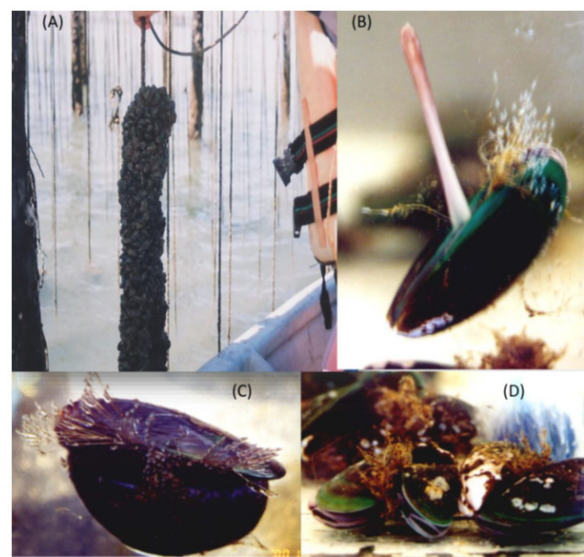


**Figure 1** (A) External view of the green-lipped mussel *Perna viridis*, showing intact shells of various sizes collected from a coastal study site. (B) Internal view of dissected *P. viridis* individuals, revealing soft tissues (gills, mantle, digestive gland) commonly analyzed for heavy metal accumulation in ecotoxicological studies.

Yet, in May 2025, as I watched one of my students dissect a *P. viridis* specimen, I was overcome with a feeling of estrangement. It was as if I were meeting this species for the first time again. This encounter – juxtaposed with the passing of my mother on 12 June 2025 – cracked open a space within me not just for memory, but for existential reflection. The mussel I had studied scientifically for years suddenly took on a deeper symbolism in the context of loss and survival.



**Figure 2** (A) The author collecting *P. viridis* at a floating aquaculture platform (*sangkar ikan*) in Pantai Sri Tujuh, Kelantan (2004). (B) The author inspecting a jetty pole for attached *P. viridis* in Kampung Pasir Puteh, Johore (1998). These images illustrate the long-term personal and scientific engagement with this species.



**Figure 3** (A) Rope culture of *P. viridis* showing dense colonization of mussels in a suspended aquaculture system. (B) A live *P. viridis* extending its muscular foot, used for attachment during early settlement. (C) Two individuals of *P. viridis*.

with byssal thread attached to a the aquarium wall (submerged substrate), exemplifying the species' tendency to aggregate and persist in both natural and farmed habitats. (D) Three individuals of *P. viridis* with valves slightly opened, actively filter-feeding on suspended particles, in an aquarium.

For the objectives and rationale in this article, I reflect on my long journey with *P. viridis*, blending factual ecological insights with personal contemplation. The objective is to illustrate how integrating reflection with ecology can yield new insights into both marine life and the human condition. For the *International Journal of Hydrology* readership, this perspective offers a complementary view of an aquatic invasive species—one that goes beyond datasets to consider emotional and philosophical dimensions. By intertwining scientific observations with introspection, I hope to demonstrate the value of connecting empirical research to personal meaning, thereby enriching our understanding of marine ecology and how we communicate science.

### Biological marvel and ecological invasiveness

Over the years, I have come to appreciate *P. viridis* not just as a subject of study, but as a marvel of biological tenacity. When I first encountered this species, I was captivated by its ability to thrive on the margins—flourishing in waters others might consider hostile. Scientifically, *P. viridis* is native to tropical and subtropical coasts of Asia, but it has become an invasive species in distant regions (for example, establishing rapidly in Tampa Bay, USA and altering local ecosystems). The mussel's broad environmental tolerance is well documented: it can survive in water temperatures from approximately 9–35°C and withstand a range of salinities, though prolonged low-salinity conditions impose limits.<sup>2</sup> Its life history traits – rapid growth, early maturity, and high reproductive output – have made it a successful colonizer of new habitats.<sup>3</sup>

Notably, *P. viridis* also provides ecological services even as it invades. It is a filter feeder that bioaccumulates pollutants, serving as a natural biomonitor of coastal water quality.<sup>4,5</sup> By concentrating heavy metals and other contaminants in its tissues, this mussel gives us critical information about the health of marine environments. Such duality in its role – both a disruptive invader and a useful environmental indicator – frames *P. viridis* as an ecological paradox.

Despite the species' capacity to outcompete native bivalves and alter habitats (e.g., displacing native oysters like *Crassostrea virginica*),<sup>6</sup> I find it difficult to condemn *P. viridis*. Like many of us, the mussel did not choose where it landed. It simply made do with the circumstances—surviving, adapting, and sometimes overwhelming other species unintentionally. This more empathetic view has changed how I regard the so-called “enemy” species.

Indeed, the paradox of *P. viridis* inspires admiration alongside concern. An organism cast as an ecological villain can also be an ally in understanding the costs of human activity on coastal systems. Its very presence in polluted waters is a living testament to both our environmental impacts and nature's resilience. I have grown to respect that nuance. *P. viridis*, misunderstood and miscategorized by some, carries quiet wisdom about survival if we are willing to look closely enough.

### Survival and the spirit of never giving up: lessons from nature

What strikes me most about *P. viridis* is its spirit of never giving up. Biologically, this mussel displays remarkable adaptability. Populations from nutrient-rich, oxygen-poor waters develop greater tolerance to low oxygen.<sup>7,8</sup> It also shows a preference for natural,

textured substrates when settling, even along urbanized coastlines – a nuanced survival strategy that maximizes stability in new environments.<sup>9</sup> These scientific observations reveal a creature fine-tuned to persist in changing conditions.

On a personal level, such facts have taken on metaphorical meaning. After losing my mother, I realized that survival is not just a matter of breathing or eating; it is about finding meaning. Just as the mussel filters out toxins and nourishes itself in murky waters, we humans must filter out negativity and seek purposeful nourishment in our lives. *P. viridis*' ability to endure hardships became, for me, a symbol of spiritual and psychological perseverance in the face of grief.

The grief of my mother's passing has been profound. It reminds me that survival involves more than filling the stomach—it also means fulfilling the soul. The mussel's quiet persistence now reads like a prayer of determination, a “biology of belonging” that speaks to the importance of finding one's place. In the survival of *P. viridis*, I perceive not only an ecological model but an existential metaphor. We, too, must find a firm substrate to cling to (Figure 3), filter what we take in, and withstand the toxins of our time. In this way, a humble mussel's life cycle mirrors the human journey of resilience and hope.

### The FIKR framework: A Mussel's wisdom for humanity

The Arabic word *fikr* (فكر) means “thought” or “reflection.” Through the conceptual lens of FIKR—Facets, Insights, Knowledge, and Resilience<sup>10</sup>—I have begun to reframe my lifelong study of *P. viridis* in a broader human context. (Note: FIKR was originally developed as an organizational psychology framework, but here it is adapted as a cross-disciplinary reflective tool aligning with environmental psychology and science education; see Yap et al.,<sup>10,11\*</sup> Instead of asking only traditional scientific questions about physiology or distribution, I now also ask: *What allows this mussel to survive, persist, and even thrive in waters stressed by human impact? What quiet wisdom resides in its steadfast grip on the rocks amid chaos?* In exploring these questions, *P. viridis* has evolved in my mind from a research subject into a personal symbol—a mirror reflecting my own struggles, hopes, and capacity for endurance.

Using the FIKR perspective, I distill the lessons of *P. viridis* into four facets:

- I. Facets: This mussel is not just a species; it wears many hats in its ecosystem. *P. viridis* is a source of food, a biological filter of the water, and a pollution sentinel that signals environmental degradation.<sup>12</sup> It has even become a spiritual metaphor in my life. Like people, it carries multiple roles with quiet dignity. This multifaceted identity reminds me that I too have many roles—scientist, educator, mentor, husband, father, son, and now mourner—and that all these facets can coexist with purpose.
- II. Insights: The ability of *P. viridis* to alert us to pollution offers more than data; it offers insight. The mussels' sensitivity to contaminants reveals how vulnerability can be a strength. In parallel, human emotions—our sadness, stress, or joy—are signals alerting us to imbalances in our lives. What we observe in mussels (for instance, their stress responses to toxins) can help us better understand ourselves and the need to respond when our environment, internal or external, is unhealthy.
- III. Knowledge: Decades of research and dozens of papers have only scratched the surface of what *P. viridis* can teach us. One key lesson is that knowledge is not just about accumulation of facts, but also about contemplation. Even a simple mussel can

become a lifelong teacher if we are willing to listen and reflect. This perspective reinforces the idea that scientific knowledge benefits from pauses for thought, much like in education where reflection can deepen learning beyond rote facts.

IV. Resilience: Despite coastal pollution, warming oceans, and human interference, *P. viridis* continues to survive and even proliferate. Its quiet, uncelebrated persistence is a lesson in resilience. In my mourning and healing, I look to these mussels as models of how to carry on through life's upheavals. Their example encourages me to cling to what is meaningful, filter out life's toxins, and stay rooted even as tides of change sweep through—exactly the qualities we humans need to navigate adversity.

These FIKR reflections have reshaped not only my understanding of a species I've studied for so long, but also my understanding of life itself. The mussel has become more than a research subject—it is now entwined with my philosophy. Importantly, applying the FIKR framework in this marine context builds bridges to broader disciplines. The Facets and Resilience dimensions highlight themes in marine ecology (such as the organism's ecological roles and adaptability), while Insights and Knowledge speak to science education and communication (learning from nature and the importance of reflective understanding). In essence, this integrative approach echoes principles of environmental psychology by linking human experience and emotion with ecological understanding.<sup>11</sup> By repurposing a conceptual tool across disciplines, we see how personal reflection and ecological science together can yield a more holistic appreciation of the natural world.

Therefore, although the FIKR framework originates from organizational psychology,<sup>10,11</sup> its principles—facets, insights, knowledge, and resilience—are transferable to environmental contexts. By applying it to *P. viridis*, the framework becomes a tool for interpreting ecological adaptability, informing environmental psychology, and enhancing science education through relatable conceptual models.

## Discussion and implications

Beyond the specifics of *P. viridis* biology, this blended reflective–scientific approach offers broader insights for marine ecology, invasive species management, and science communication. As someone who has dedicated much of my academic life to *P. viridis*, I now find it increasingly difficult to view this mussel purely as an “invasive threat.” To me, *P. viridis* embodies a productive paradox—an ecological outsider that has become an insider in my intellectual and emotional world. Yes, it can alter native ecosystems, outcompete other species, and spread rapidly. But it also teaches us, warns us, and mirrors our changing coastal realities in the Anthropocene. In terms of marine ecology, acknowledging this dual narrative encourages a more nuanced understanding of species often labelled simply as pests; it highlights the complex roles such organisms play in ecosystems, from competition to ecosystem services.

When it comes to invasive species management, my reflections suggest that effective strategies require more than technical interventions—they demand emotional and ethical insight as well. Can we control or eradicate a species while still learning from it? Can we act without viewing nature as the enemy? Traditional responses like manual removal have their place in controlling *P. viridis* populations,<sup>13</sup> but my experience argues for adaptive management grounded in ecological respect and human humility.<sup>14,15</sup> As climate change continues to reshape coastlines and thermal regimes, *P. viridis*

will remain a living barometer of environmental shifts. Whether it flourishes or fades, its fate will remind us that our responses to nature must be as nuanced as nature itself. A reflective stance in management fosters empathy and caution, potentially leading to more thoughtful and socially acceptable interventions in dealing with invasive species.

Finally, this reflective–scientific approach carries important implications for science communication and education. Weaving personal narrative into scientific discourse can make the science more accessible and meaningful to broader audiences. As an educator, I have come to see *P. viridis* not just as a research topic but as a compelling teaching tool—one that can introduce students and the public to concepts of environmental monitoring, resilience, and even environmental ethics in an engaging way. By sharing the emotional and philosophical context alongside the empirical facts, we invite readers and students to connect with the material on a human level. Such an approach can bridge the gap between technical knowledge and personal relevance, fostering greater empathy for environmental issues. In short, integrating reflection with ecology can enrich science communication by turning data into stories and lessons that resonate beyond the laboratory.<sup>16</sup>

## Conclusion

In *P. viridis*, I see my life's work, my personal evolution, and a profound symbol of survival. It is not just a mussel; it is also a reminder to breathe, to filter, to adapt, and to continue in the face of adversity. Within the mussel's shell lies a mirror to our own humanity, especially in times of loss, change, and introspection. Through the biology of this species, we rediscover the wisdom of quiet endurance. Ultimately, this reflective journey with *P. viridis* underlines the scientific relevance of the species as a model for resilience in marine ecosystems, and its educational value as an integrative tool that connects empirical science with personal meaning. By balancing heart and mind, the story of the green-lipped mussel becomes more than an ecological case study—it becomes a testament to survival that speaks to both nature and the human spirit. Beyond my personal resonance, this study demonstrates how *P. viridis* research can serve as a valuable model for environmental monitoring, ecological ethics, and science education, reinforcing the role of marine organisms as both research subjects and catalysts for public environmental awareness.

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## Conflicts of interest

The author declares there is no conflict of interest.

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