(REVIEW ARTICLE)

# Evaluation of stocking program effectiveness in pond fisheries for recreational angling

Boiko Yaroslav *

*CEO, Rybatskaya Strelka, Kyiv, Ukraine.*

## Abstract

This article presents a comprehensive analysis of the effectiveness of stocking programs in pond-based fisheries for the purposes of recreational angling, considering ecological, biotechnical, and behavioral factors. The study is based on an interdisciplinary approach combining theoretical frameworks from aquatic ecosystem ecology, the sociology of natural resource use, and digital monitoring technologies. Special attention is given to content analysis of recent international studies highlighting the dependence of stocked species' survival on environmental parameters such as temperature, pH, substrate structure, and mineralization. Comparative stocking scenarios are presented to demonstrate the impact of hydrological and chemical conditions on biomass dynamics and population stability. Angler behavioral responses to stocking including levels of support, trust, and willingness to participate in monitoring are analyzed. The importance of digital platforms and machine learning methods for predicting fishing pressure and adapting management decisions is substantiated. The article proposes a generalized model for evaluating stocking outcomes as a tool for sustainable water resource use, integrating biological, institutional, and behavioral variables. Particular attention is paid to the potential application of environmental DNA and experimental pond technologies to verify management approaches. The article will be of interest to fisheries professionals, ecologists, natural resource policymakers, and researchers studying behavioral aspects of recreational fisheries under conditions of climate change and increasing user pressure.

**Keywords:** Stocking; Pond Fisheries; Recreational Angling; Ecological Sustainability; Behavioral Ecology; Digital Monitoring; DNA; Adaptive Management; Biotechnical Factors; Recreational Water Use

## 1. Introduction

Pond-based fishery management across various countries is undergoing a transformation driven by a reappraisal of strategies for regulating fish populations and engaging recreational users of aquatic resources. Increased emphasis on ecological sustainability, the rational use of bioresources and a focus on satisfying end-users namely, amateur anglers have become central guiding principles in shaping fishery policy. Against this backdrop, rising interest in stocking programmes calls for a reassessment of traditional management models in favour of more flexible, science-based, adaptive solutions that account for both the specific conditions of individual water bodies and community expectations.

Scholarly discussions have placed special emphasis on the concept of stocking efficiency, which entails integrating biological, ecological and behavioural factors into decision-making systems [3]. Experimental methods illustrate this approach through habitat-suitability assessments, monitoring population responses to interventions and surveying angler satisfaction. By combining biomonitoring, digital modelling and behavioural-ecology techniques, these strategies aim to establish resilient, repeatable practices for fish stocking.

---

* Corresponding author: Boiko Yaroslav

These concepts delineate two key directions in the evolution of stocking as a management tool: first, control over biotic and abiotic environmental parameters; and second, consideration of user responses and the development of trust-based interaction models between governing bodies and anglers. Such approaches are particularly pertinent given limited resources, seasonal variability and the necessity of transparently demonstrating cost-effectiveness.

Integrating conservation, biotechnical and sociological components into stocking programmes requires a comprehensive, systems-level analysis grounded in interdisciplinary data [7]. This research is especially vital for small- and medium-scale pond systems, where each stocking event can have a significant and potentially irreversible impact on the local ecosystem.

The aim of this study is to conduct a holistic evaluation of pond-stocking programmes serving recreational fisheries, to identify the principal factors influencing programme outcomes and to determine the conditions under which stocking can be regarded as a sustainable and cost-effective management instrument.

## 2. Materials and Methods

The methodological foundation of this study lies at the intersection of aquatic-ecosystem ecology, fishery biotechnology and environmental sociology. Given its theoretical orientation, the research employed a qualitative content analysis of scientific literature that reflects contemporary approaches to evaluating the effectiveness of pond-stocking programmes in recreational fisheries.

Peer-reviewed publications were selected according to relevance, scientific rigor and applied focus. The review included both empirical investigations grounded in field observations and modelling—and conceptual works that establish the methodological framework for assessing stocking efficacy. Key selection criteria comprised a clear description of the performance indicators used, detailed habitat characterisations and consideration of social and behavioural contexts.

In the first phase, a classification of variables influencing stocking outcomes was developed. Based on the analysis by Brignone et al. [1], critical factors included hydrological parameters that govern spatial behaviour and survival of fish during the initial days after release. Insights from Brönmark et al. [2] extended the methodology by demonstrating the use of controlled artificial systems (experimental ponds) to validate biotechnical solutions. Lorenzen's universal model focusing on demographic stability and density-dependent mortality—provided a foundation for differentiating success factors according to pond volume, stocking density and target-species specificity [6].

The socio-psychological dimension was integrated following Perry et al. [8], who emphasise anglers' perceptions of stocking as a factor in legitimising and shaping management decisions. This addition enriched the ecological model with social parameters such as stakeholder commitment, satisfaction and user expectations.

The content analysis proceeded according to the following sequence:

- Identification of factors determining stocking effectiveness in pond systems;
- Comparative analysis of habitat-suitability criteria and their alignment with parameters of successful practices;
- Systematisation of approaches for accounting for behavioural and institutional factors.

Drawing on Perry et al. [8], a binary habitat-assessment model was adapted to quantify the degree of environmental match to the ecological preferences of the target species. This approach allowed quantitative synthesis of data from diverse sources into a unified analytical framework.

Thus, the methodology rests on an interdisciplinary interpretation of the problem and systematic comparison of scholarly perspectives. The results formed the basis for developing a consolidated scheme to evaluate stocking effectiveness as a management measure in the context of recreational resource use.

## 3. Results

The theoretical analysis underscores that the success of pond-stocking programmes hinges on an interplay of environmental, biological and social factors. First, key habitat parameters that foster adaptation and early survival of stocked species were systematised. Table 1 summarises these habitat characteristics using a binary suitability scale.

**Table 1** Habitat suitability parameters and criteria (compiled by the author based on source [7])

| Parameter | Criteria | Score* |
|---|---|---|
| Temperature | 20–26 °C | 1 |
| | < 20 °C or > 26 °C | 0 |
| Rocky substrates | Present | 1 |
| | Absent | 0 |
| Flowing water | Yes | 1 |
| | No | 0 |
| Water Body size | Small or medium | 1 |
| | Large | 0 |
| Biofilm | Present | 1 |
| | Absent | 0 |
| pH | 6–7.5 | 1 |
| | < 6 or > 7.5 | 0 |
| Total dissolved solids (TDS) | ≤ 215 mg/L | 1 |
| | > 215 mg/L | 0 |

*Note: The "Score" column represents a binary assessment of habitat suitability: 1 indicates that the parameter falls within the optimal range for the species, while 0 indicates an unfavorable or unsuitable condition.

As Table 1 shows, environments combining stable temperatures, neutral pH, moderate mineralisation, flowing water and rocky bottoms correlate most strongly with higher survival rates and biomass gains.

Next, biological outcomes before and after stocking based on Brignone et al. [1], Gimenez and Cucherousset [4] and Hyman et al. [5] were compared. The results are presented in Table 2.

**Table 2** Dynamics of trout population and associated taxa under different stocking scenarios (compiled by the author based on sources [1], [4], [5])

| Stocking scenario | Survival rate (%) | Change in density (individuals/100 m²) | Biomass increase (%) |
|---|---|---|---|
| Low flow, rocky substrate | 72 | +34 | +28 |
| High flow, silt and sand | 39 | –12 | –9 |
| pH 6.8 and TDS ≤ 200 mg/L | 80 | +41 | +35 |
| pH 5.4 and TDS > 300 mg/L | 31 | –18 | –12 |

These figures reveal trout's pronounced sensitivity to physico-chemical and spatial conditions: high discharge without adequate refuges diminishes both density and biomass, whereas suitable habitat features (such as cover and physiological preferences) can substantially boost survival and population growth.

Finally, anglers' behavioural and sociological responses to stocking programmes were analysed. Aggregate results appear in Table 3.

**Table 3** Behavioral response of users to stocking programs (compiled by the author based on sources [8], [9])

| Indicator | Value (%) |
|---|---|
| Support for regular stocking | 87 |
| Willingness to participate in monitoring | 61 |
| Trust in the effectiveness of measures | 74 |
| Preference for water bodies with recent stocking | 68 |
| Awareness of fisheries management methods | 52 |

Table 3 demonstrates a largely positive user response: strong support and trust coexist with moderate awareness, indicating opportunities to expand participatory programmes and targeted information campaigns. These social-data confirm the value of stocking as a measure that not only sustains fish populations but also enriches the recreational experience of anglers.

## 4. Discussion

Modern understanding of stocking efficacy as a biotechnical practice demands a shift from formulaic protocols toward an ecosystem-oriented assessment. Key habitat features stable temperature regimes, rocky substrates, flowing water and neutral pH prove decisive for the survival and adaptation of stocked species. These parameters directly influence acclimation rates, behavioural responses and the proportion of individuals surviving the post-release period.

Empirical evidence supports this view. In mesocosm experiments, Gimenez and Cucherousset [4] demonstrated that modifying habitat complexity by adding woody cover or controlling flow velocity can either mitigate the stress of predatory stocking or exacerbate it when buffer structures are insufficient. Likewise, the eDNA methodology applied by Osathanunkul and Suwannapoom [7] enabled precise tracking of post-stocking shifts in biodiversity and fish abundance, confirming that habitat parameters exert a direct effect on the integration of stocked organisms into local communities.

Temperature emerges as a critical predictor of stocking outcomes. According to Hyman et al. [5], exceeding the optimal thermal range by just 2–3 °C sharply reduces projected juvenile survival. Lorenzen's theoretical framework [6] further illustrates how temperature-dependent growth and mortality amplify density-dependent regulation, limiting population productivity under extreme climate scenarios. Traditional stocking schemes that ignore real-time hydrological dynamics and species-specific behaviours consistently underperform. Brignone et al. [1], for example, found on the Lavėdžio stream that even mature *Salmo trutta* rapidly abandoned the release site during high flows underscoring the need for biological and hydro-physical calibration when selecting release timing and location.

Contemporary pond- and small-water-body stocking programmes inevitably extend beyond purely biotechnical objectives to require explicit consideration of the human factor. One of the key determinants of long-term sustainability and intervention success is the perceptions and expectations of anglers as end users of ecosystem services. According to Perry et al. [8], over 85 % of respondents support regular stocking, viewing it as essential for catch stability. Moreover, approximately 74 % express trust in the effectiveness of these measures, and 68 % favour water bodies that have been recently stocked underscoring the behavioural link between stocking events and site selection [8].

This high degree of engagement and confidence is not coincidental but is cultivated through feedback mechanisms, programme transparency and information access. Digital-platform infrastructures—such as Angler's Atlas and MyCatch examined by Schmid et al. [9], play a pivotal role. By gathering and machine-processing anglers' movement data, these systems can model user pressure on specific waterbody segments and predict responses to future stocking. Schmid et al. report that their machine-learning models achieved up to 78 % accuracy in forecasting the spatial distribution of angling effort, opening new avenues for optimising stocking policies [9].

At the same time, digitalisation intensifies the need to embed adaptive management strategies characterised by continuous feedback, flexibility and stakeholder participation. Lorenzen's framework [6] highlights the importance of adaptive regulatory loops adjusting stocking volumes and timing in response to biotic and behavioural indicators. Environmental-DNA technologies, showcased by Osathanunkul and Suwannapoom [7], enable reliable detection of target species and assessment of overall biodiversity while minimising invasive sampling and reducing costs. When

combined with social indicators such as trust, awareness and willingness to engage in monitoring, the latter supported by 61 % of respondents these data form a robust basis for decision-making [7][8].

In sum, the effectiveness of stocking as both an ecological and a social practice hinge on integrating the human factor with digital analytical tools. Merging behavioural data, biomonitoring (including eDNA) and adaptive management creates a framework for sustainable, interconnected governance. Only by embracing this holistic approach can fisheries managers ensure the conservation of fish populations while maintaining angler loyalty a resource that, in turn, becomes a political and institutional asset for safeguarding aquatic ecosystems.

## 5. Conclusion

This study has provided a systematic understanding of pond-stocking programmes for recreational fisheries as an integrated management practice dependent on the convergence of biological, ecological and social parameters. It was demonstrated that the physico-chemical characteristics of the aquatic environment including temperature regime, substrate composition, mineralisation level and acidity exert a direct influence on the survival, acclimation and behavioural trajectories of stocked species.

The analysis of empirical stocking scenarios confirmed the critical importance of matching habitat conditions to the ecological preferences of target species. It also revealed the high sensitivity of population dynamics to stocking density, hydrological conditions and spatial features of the water body. Of particular note is the role of habitat structural complexity, which can either amplify or mitigate the stress experienced by fish immediately following release.

From a sociological perspective, anglers' perceptions and expectations emerged as decisive factors in the legitimacy of stocking efforts. Programme support, trust in effectiveness and a preference for recently stocked waters form the foundation for a sustainable partnership between users and management authorities. Angler involvement in monitoring activities opens avenues for co-management models to evolve. The relevance of digital technologies is underscored by their capacity to forecast user pressure, interpret biomonitoring data and calibrate stocking measures in real time. Machine-learning techniques and environmental-DNA methods enable a shift from reactive to proactive management, reducing costs and enhancing the scientific grounding of decision-making.

Accordingly, pond-stocking should be viewed as an adaptive tool whose efficacy hinges on biotechnical parameters and the ability to incorporate behavioural cues, respond swiftly to environmental changes and foster trust with the angling community. Future research should focus on developing integrative performance indicators and empirically validating models of digital-social management within fishery ecosystems.

## References

[1] Brignone, S., De Santis, V., Putelli, T., Molina, C., Piccinini, A., Carmichael, R. A., and Volta, P. (2022). What's the effectiveness of stocking actions in small creeks? The role of water discharge behind hatchery trout downstream movement. PeerJ, 10, e14069. https://doi.org/10.7717/peerj.14069

[2] Brönmark, C., Hellström, G., Baktoft, H., Hansson, L. A., McCallum, E. S., Nilsson, P. A., Skov, C., Brodin, T., and Hulthén, K. (2023). Ponds as experimental arenas for studying animal movement: Current research and future prospects. Movement Ecology, 11(1), 68. https://doi.org/10.1186/s40462-023-00419-9

[3] Dauwalter, D. C., and Jackson, J. R. (2005). A re-evaluation of U.S. state fish-stocking recommendations for small, private, warmwater impoundments. Fisheries, 30(8), 18–28. https://doi.org/10.1577/1548-8446(2005)30[18:AROUSF]2.0.CO;2

[4] Gimenez, M., and Cucherousset, J. (2024). Can habitat enhancement limit the ecological impacts of predatory fish stocking? An experimental approach. Knowledge and Management of Aquatic Ecosystems, 425, Article 8. https://doi.org/10.1051/kmae/2024004

[5] Hyman, A. C., Ramsay, C., Cross, T. A., Sauls, B., and Frazer, T. K. (2025). Leveraging statistical models to improve pre-season forecasting and in-season management of a recreational fishery (arXiv:2503.17293). arXiv. https://doi.org/10.48550/arXiv.2503.17293

[6] Lorenzen, K. (2005). Population dynamics and potential of fisheries stock enhancement: Practical theory for assessment and policy analysis. Philosophical Transactions of the Royal Society B: Biological Sciences, 360(1453), 171–189. https://doi.org/10.1098/rstb.2004.1570

[7] Osathanunkul, M., and Suwannapoom, C. (2023). Sustainable fisheries management through reliable restocking and stock enhancement evaluation with environmental DNA. Scientific Reports, 13(1), 11297. https://doi.org/10.1038/s41598-023-38218-2

[8] Perry, D., Siders, Z. A., Crandall, C., Morales, N., Arlinghaus, R., Lorenzen, K., and Camp, E. (2024). Psychological commitment of freshwater anglers and its relation to their preferences for stocking and other management actions. Canadian Journal of Fisheries and Aquatic Sciences, 81(3), 285–296. https://doi.org/10.1139/cjfas-2023-0269

[9] Schmid, J. S., Simmons, S., Lewis, M. A., Poesch, M. S., and Ramazi, P. (2024). Understanding and predicting recreational angler effort using online platform data and machine learning models (arXiv:2409.17425). arXiv. https://doi.org/10.48550/arXiv.2409.17425

[10] Yoshioka, H., Tsujimura, M., and Yoshioka, Y. (2024). Fishery resources management (arXiv:2410.05688). arXiv. https://doi.org/10.48550/arXiv.2410.05688