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PERFORMANCE INDICATORS OF JUVENILE SNOOK (*Centropomus undecimalis*) IN FRESHWATER AND MARINE FARMING CONDITIONS

Saeko Gaitán-Ibarra
Universidad del Magdalena, Santa Marta, Colombia
Correspondence author

Mayra de León-Miranda
Universidad del Magdalena, Santa Marta, Colombia

Sara Cruz-Botto
Universidad del Magdalena, Santa Marta, Colombia

Abstract: The common snook (*Centropomus undecimalis*) is emerging as a promising candidate for aquaculture due to its broad salinity tolerance and high commercial value. However, comparative data on its performance in freshwater and marine culture systems remain limited. This study evaluated the growth performance, feed utilization, survival, and water quality parameters of juvenile *C. undecimalis* reared under controlled freshwater and marine conditions. A total of 150 juveniles were evenly distributed between the two environments, with three replicates per treatment. Fish were fed a standardized diet, and key performance indicators—including weight gain, length gain, specific growth rate (SGR), feed efficiency ratio (FER), feed conversion ratio (FCR), condition factor (K), and survival—were monitored over the experimental period. Results showed no statistically significant differences between treatments in any of the zootechnical parameters, suggesting that *C. undecimalis* can adapt equally well to both salinity regimes. Significant differences were found in water quality variables (pH, hardness, temperature, salinity, and dissolved oxygen), but these did not impact fish performance. These findings highlight the species' physiological resilience and underscore its potential for flexible cultivation strategies in coastal or inland aquaculture systems. Further research is recommended to optimize diet formulations and assess reproductive performance across rearing environments
Keywords: physiological plasticity, growth, zootechnical performance, water chemistry, tropical aquaculture

INTRODUCTION

Aquaculture is among the most dynamic and rapidly expanding food production sectors globally, largely driven by the rising demand for high-quality protein and the need to relieve pressure on overexploited wild fisheries (FAO, 2020). In Colombia, aquaculture has experienced sustained growth over the past decade, with species such as tilapia, trout, cachama, and shrimp leading production outputs (Gaitán-Ibarra & Villamizar-Villamizar, 2024). However, expanding the range of cultivated species remains a strategic imperative to enhance the resilience and economic value of both inland and coastal aquaculture systems. One candidate species that has attracted significant attention is the common snook (*Centropomus undecimalis*), due to its high market value, consumer acceptance, and its physiological adaptability to both freshwater and marine conditions (Álvarez-Lajonchère & Tsuzuki, 2008; Rhody et al., 2014).

C. undecimalis is a carnivorous euryhaline teleost with protandric hermaphroditism, exhibiting notable tolerance to wide ranges of salinity and dissolved oxygen levels—traits that support its suitability for intensive aquaculture (Gracia-López et al., 2006; Vidal-López et al., 2012). Its native range extends from the southeastern United States to the Caribbean and northern South America, where it supports both artisanal fisheries and nascent aquaculture initiatives (Grijalba-Bendeck et al., 2017). Given its ecological plasticity, the species has been experimentally evaluated under contrasting salinity regimes to optimize reproductive and productive traits. Recent findings indicate that feminization using 17β-estradiol (E2) is effective in producing functional females and that freshwater rearing conditions can improve zootechnical performance by enhancing feed conversion and reducing osmotic stress (Contreras-García et al., 2023; Gaitán-Ibarra & Villamizar-Villamizar, 2024).

Water quality plays a pivotal role in the success of snook culture, influencing survival, growth, and reproductive outcomes. Recommended freshwater parameters for juveniles include temperatures between 28–32 °C, dis-

solved oxygen levels above 5 mg/L, and salinity below 2 ppt, whereas marine systems generally require 22–30 °C and 25–35 ppt salinity, with oxygen levels above 4 mg/L (Vidal-López et al., 2012; Gaitán-Ibarra, 2025). Proper control of variables such as pH, alkalinity, and nutrient concentrations is essential to maintain physiological homeostasis, particularly during hormonal treatments.

Besides environmental conditions, zootechnical indicators—such as specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), and survival—are essential for evaluating culture efficiency (Gaitán-Ibarra, 2025). Research on diet formulation has shown that replacing fishmeal with up to 35% soybean meal does not compromise growth performance and may enhance feed efficiency while reducing costs (Arriaga-Hernández et al., 2021; Gaitán-Ibarra et al., 2023). Additionally, probiotic supplementation has demonstrated improvements in growth, erythrocyte morphology, and immune function in freshwater-reared juveniles (Gaitán-Ibarra, 2025).

In the Colombian Caribbean, recent efforts have focused on developing standardized protocols for snook aquaculture, including optimized growth metrics, feeding strategies, and survival benchmarks (Gaitán-Ibarra & Villamizar-Villamizar, 2024). Nonetheless, comparative evaluations of performance under freshwater versus marine conditions remain limited. Addressing this knowledge gap is critical to inform best practices for culturing *C. undecimalis* and to support the sustainable expansion of aquaculture involving emerging species.

Therefore, the main objective of this study is to assess the effects of water quality on key zootechnical indicators of juvenile *C. undecimalis* reared in freshwater and marine environments. Specifically, it aims to (i) estimate growth parameters under both conditions, (ii) evaluate the influence of salinity on growth dynamics, and (iii) determine survival rates during the rearing period. The outcomes of this research will offer valuable insights for aquaculture practitioners and contribute to the diversification and sustainability of tropical fish farming systems.

MATERIALS AND METHODS

STUDY AREA AND EXPERIMENTAL DESIGN

This study was carried out at two facilities in Santa Marta, Colombia: (i) the Aquaculture Laboratory at the Experimental Farm of the Universidad del Magdalena (11°13′22.74″N, 74°11′4.86″W), and (ii) the Mariculture Laboratory at the Taganga Fisheries and Aquaculture Development Centre (11°15′58.35″N, 74°11′23.00″W). A total of 150 juvenile *Centropomus undecimalis* (mean length: 13.31 ± 0.22 cm; mean weight: 18.11 ± 0.96 g) were collected from the Ciénaga Grande de Santa Marta – CGSM (10°58′55.7″N, 74°18′29.1″W). Capture and transport procedures followed the protocol described by Polonía-Rivera et al. (2017), with minor adjustments.

Immediately after capture, fish were placed into double polyethylene bags (40 L capacity; biomass density: 0.025 kg/L) filled with ambient water from the collection site. Each bag was dosed with 0.4 mL of eugenol (98% concentration) per 40 L of water and enriched with oxygen to approximately 24 mg/L. Bags were sealed, stored in secure containers, and transported to the aquaculture facility. Upon arrival, the fish underwent an acclimation protocol aligned with the salinity measured at the collection site (5–7 ppt). For the freshwater treatment (T1), salinity was gradually decreased by 3 ppt every 24 hours until reaching 0 ppt. For the marine treatment (T2), salinity was increased by 5 ppt every 24 hours until

it reached 36 ppt, completing the transition in approximately 7 days. Water temperature was maintained at 29 °C throughout. A prophylactic salt bath (10 ppt) was administered prior to the start of the experiment to minimize pathogen incidence.

Juveniles were randomly assigned to the two treatment groups (T1: freshwater; T2: marine), each with three replicate tanks containing 25 fish. Tanks were continuously aerated, and water turnover was carefully regulated. Daily management routines included feeding, removal of uneaten feed, and monitoring of water quality parameters.

FEEDING PROTOCOL AND DIET PREPARATION

Fish were fed three times daily (09:00 h, 13:00 h, and 17:00 h) at a feeding rate of 5% of the total biomass. The diet consisted of a 1:1 blend of commercial powdered trout feed (45% crude protein) and minced *Opisthonema oglinum* (commonly known as "Machuelo"). The ingredients were weighed, homogenized, and processed into pellets to improve intake and reduce feed loss. Feed rations were adjusted every two weeks based on updated biomass measurements.

WATER QUALITY MONITORING

Water quality parameters were monitored both daily and monthly. Daily assessments included temperature (°C), dissolved oxygen (mg/L), and pH, using a digital multiparameter probe (Thermo Scientific Orion Star A121) and a portable oxygen meter (WTW Oxi 3310). Monthly measurements of nitrite (µg/L), nitrate (mg/L), ammonium (mg/L), hardness (mg/L), alkalinity (mg/L), salinity (ppt), and electrical conductivity (µS/cm) were performed using a multiparameter photometer (HI83300). These assessments ensured compliance with optimal ranges for *C. undecimalis* culture, enabling prompt corrective actions if necessary.

GROWTH PERFORMANCE AND SURVIVAL

Standard length (cm) and total weight (g) were recorded for all individuals. Measurements were taken at stocking, every two weeks during the first 45 days, and monthly thereafter. The following zootechnical performance indicators were calculated (Zheng et al., 2022):

- Length Gain (cm/day) = (Final length – Initial length) / Number of days
- Weight Gain (g/day) = (Final weight – Initial weight) / Number of days
- Specific Growth Rate (SGR, %/day) = [ln(Final weight) – ln(Initial weight)] / Number of days × 100
- Condition Factor (K) = Weight / Length^3 × 100
- Feed Efficiency Ratio (FER) = Weight gain / Feed intake
- Feed Conversion Ratio (FCR) = Feed intake / Weight gain
- Survival Rate (%) = (Final count / Initial count) × 100

Survival was confirmed at each sampling event. Mortality was checked daily, and any deceased individuals were immediately removed to preserve water quality.

STATISTICAL ANALYSIS

To evaluate the effects of salinity on growth and survival parameters, an analysis of covariance (ANCOVA) was performed using time as a covariate. When significant differences ($p < 0.05$) were detected, post hoc multiple-range tests were applied. Prior to analysis, the assumptions of normality and homogeneity of variances were tested using the Shapiro–Wilk and Levene's tests, respectively. All statistical analyses were conducted using Statgraphics Centurion software.

RESULTS

GROWTH PERFORMANCE INDICATORS

Growth performance analyses revealed no statistically significant differences in any of the evaluated parameters between juvenile *Centropomus undecimalis* reared under freshwater and marine conditions. In terms of average length gain, fish cultured in freshwater exhibited a daily increase of 0.0466 ± 0.002 cm, while those in marine systems grew at a rate of 0.03 ± 0.001 cm per day. Despite the slightly higher values observed in freshwater treatment, the difference was not statistically significant ($p = 0.4746$), suggesting a comparable capacity for somatic growth in length under both salinity regimes when environmental conditions are properly controlled (Figure 1A). Regarding weight gain, freshwater-reared juveniles attained an average increase of 0.017 ± 0.013 g/day, whereas their marine-reared counterparts gained 0.25 ± 0.045 g/day. Although the numerical trend favored marine conditions, the difference did not reach statistical significance ($p = 0.2506$) (Figure 1B). Similarly, the specific growth rate (SGR) showed no significant variation between treatments ($p = 0.567$), with values of 0.75 ± 0.19%/day and 0.60 ± 0.13%/day recorded for freshwater and marine groups, respectively (Figure 1C). These findings indicate that, under controlled experimental conditions, juvenile snook are capable of maintaining consistent growth performance across contrasting salinity environments.

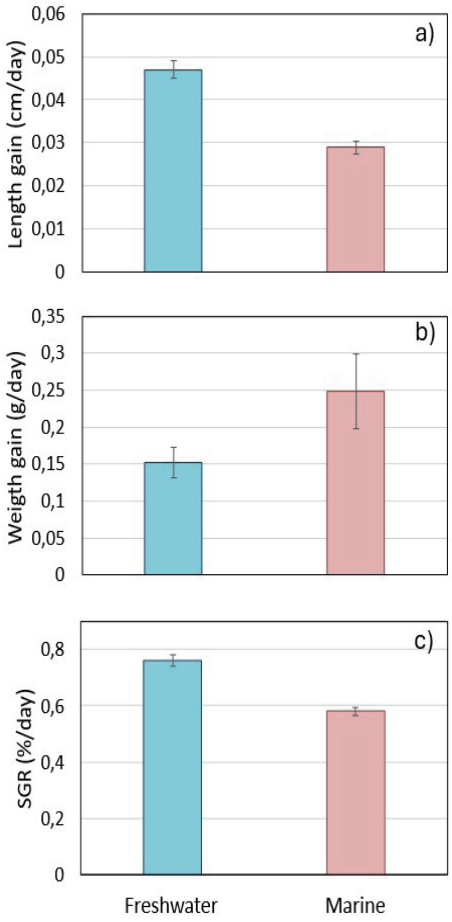

Figure 1. Comparison of performance indicators: (a) Average length gain, (b) Average weight gain, and (c) Specific growth rate of *Centropomus undecimalis* juveniles reared in freshwater and marine systems.

FEED UTILIZATION PARAMETERS

Feed utilization efficiency did not differ significantly between salinity treatments. The feed efficiency ratio (FER) was slightly higher in the freshwater group (0.24 ± 0.03) compared to the marine group (0.19 ± 0.02), although the difference was not statistically significant ($p = 0.1690$) (Figure 2A). Similarly, the feed conversion ratio (FCR) showed no significant variation between treatments ($p = 0.1335$), with mean values of 4.38 ± 0.43 for freshwater-reared fish and 5.42 ± 0.45 for those raised in marine conditions (Figure 2B). These results suggest that juvenile *Cen-*

tropomus undecimalis can utilize feed with comparable efficiency under both rearing environments, provided that other husbandry parameters remain stable.

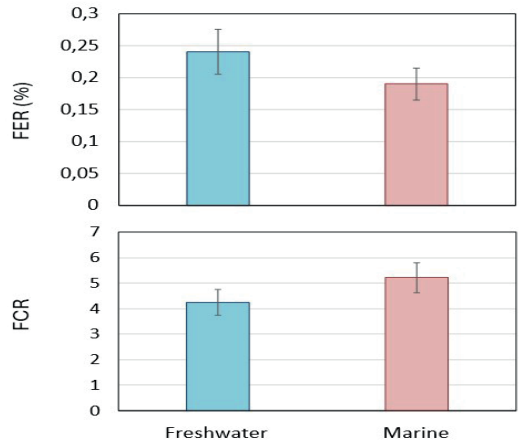

Figure 2. Comparison of feed utilization parameters: (a) Feed efficiency ratio (FER), and (b) Feed conversion ratio (FCR) of *Centropomus undecimalis* juveniles reared in freshwater and marine systems.

CONDITION FACTOR (K)

No statistically significant difference was observed in the condition factor (K) between treatments ($p = 0.567$). Juveniles reared in freshwater exhibited an average K value of 0.722 ± 0.01, while those in marine systems recorded a similar value of 0.72 ± 0.01. These results indicate that salinity conditions did not affect the body condition of *Centropomus undecimalis* during the experimental period (Figure 3).

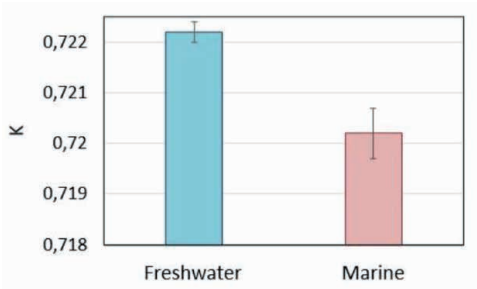

Figure 3. Comparison of condition factor (K) in *Centropomus undecimalis* juveniles reared in freshwater and marine systems.

SURVIVAL RATE

The survival rate of juvenile snook did not differ significantly between the two rearing environments. Fish maintained under freshwater conditions achieved an average survival of 82.4 ± 4.12%, whereas those cultured in marine systems reached 72.53 ± 6.99%. Despite a numerical trend favoring freshwater, the difference was not statistically validated, suggesting that *C. undecimalis* can tolerate both environments without major impacts on survival when proper management practices are applied (Figure 4).

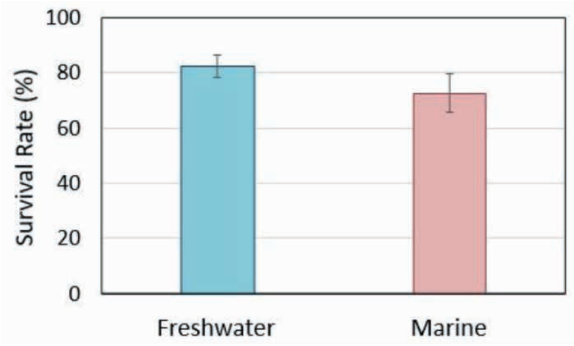

Figure 4. Survival rate of *Centropomus undecimalis* juveniles reared in freshwater and marine systems.

PHYSICOCHEMICAL PARAMETERS

Significant differences ($p < 0.05$) were observed in key physicochemical variables between the freshwater and marine culture systems used for juvenile *Centropomus undecimalis*. Specifically, hardness (mg/L), dissolved oxygen (mg/L), pH, salinity (ppm), and temperature (°C) differed notably between environments, highlighting the distinct water quality conditions associated with each system. In contrast, the remaining measured parameters showed no statistically significant variation between treatments. These findings provide a comprehensive overview of the environmental conditions maintained during the experimental period and contribute to characterizing the rearing environments. A detailed summary of the measured values, in-

cluding means, standard deviations, and significance levels, is presented in Table 1.

DISCUSSION

The present study aimed to assess the growth performance, feed utilization, and survival of juvenile *Centropomus undecimalis* under freshwater and marine aquaculture conditions. Although no statistically significant differences were found between treatments in any zootechnical parameter, several observations can be discussed in the context of previous findings.

Length and weight gains, along with the specific growth rate (SGR), were numerically higher in freshwater systems, albeit not significantly. This aligns with the findings of Mu et al. (2014), who reported similar patterns in juvenile snapper (*Lutjanus purpureus*), attributing better growth in low-salinity conditions to osmoregulatory efficiency. Similarly, López-Elías et al. (2016) identified that marine fish cultured in environments with intermediate salinities (10–20 ppt) showed enhanced growth, possibly due to reduced energy expenditure on ion regulation.

In the present experiment, the feed efficiency ratio (FER) and feed conversion ratio (FCR) also did not significantly differ between treatments. These results are consistent with those reported by Adeyemo et al. (2016) for tilapia and by Montoya-Mejía et al. (2015) for snook, where no clear advantage was found in either salinity regime when the diet was consistent across treatments. Nonetheless, Guerrero-Galván et al. (2019) noted that even slight fluctuations in water parameters, particularly salinity and temperature, may have nuanced effects on feed utilization, especially in species with euryhaline capacities such as *C. undecimalis*.

Water quality is a key driver of growth and feed conversion in aquaculture. In this study, significant differences were detected in parameters such as hardness, pH, salinity, and dissolved oxygen. These variations are not unexpected given the contrasting nature of the two environments, but they may play subtle roles in metabolic efficiency. López-Elías et al. (2016) and Vidal-López et al. (2012) have emphasized the importance of maintaining stable water chemistry within optimal ranges for snook growth: salinity (10–35 ppt), pH (7.5–8.5), temperature (27–30 °C), and low concentrations of nitrogenous waste.

Survival was high in both systems and did not differ significantly. Castro-Sánchez et al. (2019) demonstrated similar trends in *C. poeyi*, where juveniles reared in freshwater and marine conditions showed comparable survival outcomes. This supports the hypothesis that snook are physiologically resilient and can thrive under a range of salinities, given adequate acclimation and consistent husbandry practices.

Overall, the findings of this study confirm the robustness of *Centropomus undecimalis* for culture in both freshwater and marine systems. Further studies should evaluate longer-term growth performance, economic viability, and potential interactions with dietary formulations tailored to specific salinity regimes.

DISCUSSION

This study evaluated the zootechnical performance, feed utilization, and survival of juvenile *Centropomus undecimalis* reared under controlled freshwater and marine aquaculture conditions. The absence of statistically significant differences across most performance indicators suggests that the species exhibits a high degree of physiological plasticity to contrasting salinity regimes, a finding that is consistent with previous studies highlighting its euryhaline adaptability (Gracia-López et al., 2006; Vidal-López et al., 2012; Gaitán-Ibarra,

Environment	Parameter	Mean ± SD	Min	Max	p-value	Reference value
Freshwater	Alkalinity	169.7 ± 11.6	123	210	0.18	0.025
Marine	Alkalinity	197.3 ± 11.3	179	218	0.018	
Freshwater	Hardness (mg/L)	191.2 ± 21.3	167.2	297.2	0.001	0.031
Marine	Hardness (mg/L)	363.7 ± 11.9	348	387	0.019	
Freshwater	Dissolved oxygen (mg/L)	6.74 ± 0.82	4.79	7.6	0.000	0.04
Marine	Dissolved oxygen (mg/L)	5.02 ± 0.21	3.8	7.6	0.01	
Freshwater	pH	8.16 ± 0.05	7.03	8.51	0.000	0.01
Marine	pH	10.38 ± 0.23	6.5	13.3	0.002	

Table 1. Comparative analysis of water quality parameters in freshwater and marine snook (*Centropomus undecimalis*) culture systems.

2025).

Although numerical differences in length and weight gain were observed—favoring freshwater conditions—these were not statistically significant. Similar patterns have been documented by López-Elías et al. (2016) and Gaitán-Ibarra et al. (2023), who reported improved growth performance in snook and other marine fish species when reared at low salinity levels, likely due to reduced osmoregulatory demands. In euryhaline fish, the energetic cost of maintaining ionic balance in high-salinity environments may divert energy from somatic growth (Mu et al., 2014), a hypothesis that could partially explain the observed trends in this study.

Feed utilization parameters, including Feed Efficiency Ratio (FER) and Feed Conversion Ratio (FCR), also showed no significant differences between treatments. These findings align with those of Arriaga-Hernández et al. (2021), who reported that white snook (*Centropomus viridis*) achieved comparable feed performance across diets with different fishmeal replacement levels, independent of salinity. Additionally, Gaitán-Ibarra (2025) demonstrated that feeding strategies based on soybean-fishmeal blends could yield consistent feed utilization in *C. undecimalis* regardless of rearing salinity. The relatively high FCR values obtained in both environments (>4) suggest that further optimization of dietary formulations and feeding frequency is needed to improve feed conversion efficiency, as also noted by Tacon (2013) and Siddique & Hassan (2016) in comparable tropical species.

The condition factor (K), a morphometric indicator of well-being, was unaffected by salinity. This result supports findings from Castro-Sánchez et al. (2019) in *C. poeyi* and Montoya-Mejía et al. (2015) in snook, where K remained stable across salinity gradients. It reinforces the idea that, under controlled experimental conditions with adequate diet and water quality, snook can maintain optimal body condition regardless of environmental salinity.

Survival rates in this study were high (>70%) in both environments, with no significant differences between treatments. This confirms the robust adaptability of *C. undecimalis* to variable salinity, as previously documented by Rhody et al. (2014) and confirmed under Colombian conditions by Gaitán-Ibarra & Villamizar-Villamizar (2024). These findings are particularly relevant for producers in coastal regions with access to both freshwater and marine water sources, as they support the feasibility of snook farming across a range of site-specific conditions.

It is worth noting that several physicochemical parameters—such as hardness, dis-

solved oxygen, temperature, pH, and salinity—differed significantly between treatments, yet did not compromise zootechnical performance. This underscores the species' capacity to tolerate broad environmental variation, as previously reported by Grijalba-Bendeck et al. (2017) and López-Elías et al. (2016). However, it is essential to maintain these variables within optimal thresholds, as fluctuations beyond tolerance limits can trigger sublethal stress responses that may not be immediately evident in short-term growth metrics (Guerrero-Galván et al., 2019; Gaitán-Ibarra, 2025).

Taken together, the results validate *C. undecimalis* as a resilient candidate for aquaculture in both freshwater and marine settings. While no significant performance differences were detected between treatments, the observed trends highlight the importance of further investigations on long-term growth trajectories, reproductive efficiency, and cost-benefit analyses across production systems. Future studies should also examine the role of microbiota, immunophysiological responses, and nutrient digestibility under variable salinity conditions, as suggested by Contreras-García et al. (2023) and Arriaga-Hernández et al. (2021), to optimize culture protocols for this emerging tropical species.

CONCLUSION

This study demonstrated that juvenile *Centropomus undecimalis* can be cultured successfully in both freshwater and marine environments without significant differences in key performance indicators such as growth, feed utilization, and survival. The results confirm the species' euryhaline capacity and resilience to varying salinity conditions, provided that water quality and husbandry practices remain consistent. Although freshwater systems showed slightly better numerical values in growth and feed efficiency, the absence of statistical differences indicates broad adaptability. These findings support the feasibility of implementing flexible aquaculture systems for snook in diverse environmental settings, especially in regions with variable water salinity availability. Future research should focus on long-term production cycles, reproductive performance, and cost-benefit analyses to further optimize the commercial potential of *C. undecimalis* in tropical aquaculture.

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