Jurnal Akuakultur Indonesia
Research Article
ISSN: 1412-5269
EISSN: 2354-6700
Vol. 25 No. 2, July 2026
DOI: 10.19027/jai.25.2.273-281

Development and growth of female spinny lobster *Panulirus homarus* induced by laserpuncture with different time durations

Perkembangan dan pertumbuhan lobster pasir *Panulirus Homarus* betina yang diinduksi laserpunktur dengan durasi waktu berbeda

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(Received April 1, 2024; Revised January 21, 2025; Accepted April 16, 2026)

ABSTRACT

Spiny lobster (*P. homarus*) cultivation currently has good prospects due to its high economic value. However, there are obstacles to cultivating sand lobsters, such as the difficulty in providing seeds. The way that can be done to overcome this is by engineering lobsters reproduction. Laserpuncture is a method that can be used to engineer reproduction in sand lobsters by utilizing low wave helium-neon light which provides safe stimulation to accelerate the production of developmental and growth hormones in sand lobsters. Laserpuncture induction was carried out on the eye stalk and ventral part of the female sand lobster. This research used the completely randomized design experimental method with female sand lobster weighing 110 ± 5 g. This research was carried out using 4 treatments with 5 replications of each treatment. The treatments in this study were different durations of laserpuncture induction, including A (2 second induction), B (4 second induction), C (6 second induction), and K (no induction). The analysis in this study was carried out qualitatively and quantitatively which included parameters of absolute weight, absolute length, specific growth rate, length-weight relationship, gonad maturity level, and gonadosomatic index. The results showed that treatment A had the most significant effect compared to other treatments on all parameters, so that optimal laserpuncture induction on female sand lobsters could be applied for two seconds.

Keywords: development, growth, induction, laserpuncture, lobster

ABSTRAK

Budidaya lobster pasir (*P. homarus*) memiliki prospek yang bagus saat ini karena nilai ekonomis yang tinggi. Namun terdapat kendala pada budidaya lobster pasir seperti sulitnya ketersediaan benih. Cara yang bisa dilakukan untuk mengatasi hal tersebut adalah dengan melakukan rekayasa reproduksi lobster. Laserpunktur merupakan metode yang dapat digunakan untuk melakukan rekayasa reproduksi pada lobster pasir dengan memanfaatkan sinar helium-neon bergelombang rendah yang memberikan stimulasi dengan aman untuk mempercepat produksi hormon perkembangan dan pertumbuhan pada lobster pasir. Penginduksian laserpunktur dilakukan pada bagian tangkai mata dan ventral lobster pasir betina. Penelitian ini menggunakan metode eksperimental RAL dengan hewan uji lobster pasir betina dengan berat 110 ± 5 g. Penelitian ini dilaksanakan dengan menggunakan 4 perlakuan dengan 5 kali pengulangan tiap perlakuan. Perlakuan pada penelitian ini adalah perbedaan durasi induksi laserpunktur meliputi A (induksi 2 detik), B (induksi 4 detik), C (induksi 6 detik), dan K (tanpa induksi). Analisis yang ada pada penelitian ini dilakukan secara kualitatif dan kuantitatif yang meliputi parameter berat mutlak, panjang mutlak, *specific growth rate*, hubungan panjang berat, tingkat kematangan gonad, dan indeks kematangan gonad. Hasil penelitian menunjukkan bahwa perlakuan A memiliki pengaruh paling signifikan dibandingkan dengan perlakuan lainnya pada semua parameter, sehingga induksi laserpunktur secara optimal pada lobster pasir betina dapat diaplikasikan selama dua detik.

Kata kunci: induksi, laserpunktur, lobster, perkembangan, pertumbuhan

INTRODUCTION

The spiny lobster (*Panulirus homarus*) is one of the most promising fisheries commodity in Asia, especially in Indonesia (Sukenda *et al.,* 2024). Sumiati *et al.* (2023) stated that the export demand for marine lobsters in Indonesia has reached around 2,000–2,500 tons per year. In addition, *P. homarus* possesses substantial economic value. This species inhabits coastal environments characterized by rocky, coral, and sandy substrates (Sasaki *et al.,* 2025). In Indonesia, spiny lobsters are commonly distributed in the western waters of Sumatra, the southern coasts of Java and Bali, the Nusa Tenggara region, and the waters surrounding Aceh. Lobsters are primarily harvested through capture fisheries in coastal waters and subsequently cultured in floating net cages and bottom cages.

Mai and Tran (2022) reported that, in addition to aquatic environments, the culture of *P. homarus* can also be conducted in land-based aquaculture systems. Such systems include concrete tanks, circular ponds, and recirculating aquaculture systems (RAS). Despite its considerable economic prospects and aquaculture potential, the availability of market-sized lobsters for export remains insufficient to meet current demand. Lesmana and Mumpuni (2021) reported that one of the major factors contributing to limited seed availability is overexploitation resulting from excessive fishing activities. However, intensive harvesting practices may threaten the sustainability of wild lobster populations. Consequently, obtaining broodstock for aquaculture production has become increasingly challenging.

The Indonesian Ministry of Marine Affairs and Fisheries (KKP) has emphasized that expanding lobster aquaculture activities represents one of the most effective approaches to reducing pressure on wild populations while increasing production capacity. Furthermore, lobster aquaculture can be complemented by reproductive engineering techniques to accelerate reproductive development and enhance the growth performance of spiny lobsters (Koshio *et al.,* 1992).

One of the approaches to reproductive manipulation in spiny lobster aquaculture is the application of laserpuncture induction. Kusuma and Hariani (2017) described laserpuncture as an acupuncture technique applied to reproductive acupoints using low-intensity helium–neon laser irradiation, which functions as a biological tissue stimulator in lobster. Laserpuncture induction has been reported to enhance cellular activity in lobster. This technique has also been applied to aquatic organisms to accelerate reproductive cell maturation compared with natural reproductive processes (Pacheco *et al.,* 2026). Hariani *et al.* (2020) reported that laserpuncture stimulation at acupuncture points in lobstercan trigger the production of neurotransmitters. According to Biscocho *et al.* (2018), neurotransmitters transmit information through synapses and neurons to the central nervous system.

These neurotransmitters may consist of amino acid compounds, one example being gamma-aminobutyric acid (GABA). GABA can be produced through laserpuncture stimulation of nerve cells. Kusuma *et al.* (2007) explained that GABA production is induced by electromagnetic waves that generate action potentials capable of opening Ca^{2+} channels. Once these channels are activated, neurotransmitters initiate the synthesis of GABA. Furthermore, Kusuma and Hariani (2017) reported that GABA is subsequently

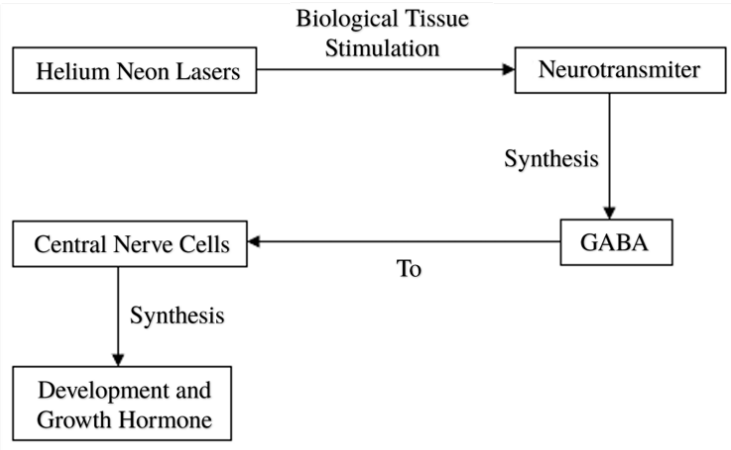

Figure 1. Conceptual framework of laserpuncture application.

transmitted to the central nervous system, where it is re-synthesized and involved in the release of growth and development-related hormones through the circulatory system or hemolymph. Therefore, the application of laserpuncture in spiny lobsters is expected to provide an alternative reproductive engineering strategy to enhance their growth and developmental performance.

MATERIAL AND METHOD

Experimental design

This study employed a completely randomized design (CRD) consisting of four treatments with five replicates per treatment. The treatments included: Treatment A (2-second laserpuncture induction), Treatment B (4-second laserpuncture induction), Treatment C (6-second laserpuncture induction), and Control Treatment K (without laserpuncture induction).

Material

The experimental fish consisted of female spiny lobsters (*Panulirus homarus*) collected from the northern coastal waters of Banyuwangi. The lobsters were size-selected to an average body weight of 110 ± 5 g and acclimatized for one week in concrete tanks at the Fisheries Training and Extension Center (BPPP) Banyuwangi. Laserpuncture induction was conducted using a veterinary laserpuncture device with an output power of 4–5 mW, a light emission area of 0.2 cm^2, and a wavelength of 632.8 nm.

Experimetal Procedure

The study conducted with preparation of culture tanks and rearing media. Concrete tanks measuring 5×2×1.5 m^3 were thoroughly cleaned by scrubbing the inner surfaces to remove attached residues. After cleaning, the tanks were air-dried for 24 hours to eliminate any remaining contaminants. Subsequently, the tanks were filled with seawater to a depth of approximately 50 cm. The seawater was disinfected using 5 g of chlorine dissolved in seawater to minimize bacterial contamination. Finally, PVC shelters were placed inside the tanks to provide refuge and substrate for the lobsters.

Following tank preparation, the lobsters underwent an acclimatization period before receiving laserpuncture treatments. Laserpuncture induction was administered once weekly over a five-week experimental period. The induction was applied at two anatomical locations: one of the X-organs located on the left eyestalk and the ventral region of the body, specifically the abdomen aligned with the fifth walking leg. Stimulation of the X-organ was intended to suppress the production of hormones that inhibit growth and development, whereas stimulation of the ventral region was aimed at enhancing feeding activity.

The rearing period for *P. homarus* lasted for five weeks. Culture management included feeding, water quality monitoring, and tank maintenance. Lobsters were fed fresh green mussels (*Perna viridis*) at a feeding rate of 10% of total biomass twice daily, in the morning and afternoon. Only mussels of good quality, indicated by dark orange to blackish-orange flesh coloration, were used as feed.

Water quality monitoring consisted of daily and weekly assessments. Daily monitoring was conducted in the morning and afternoon and included measurements of temperature, dissolved oxygen (DO), salinity, and pH. Weekly monitoring was performed once every week and included ammonia, nitrite, and nitrate measurements. Tank maintenance was conducted through siphoning every two days to remove waste and uneaten feed. Following siphoning, a 50% water exchange was performed using the recirculation system.

Body weight and total length measurements were conducted weekly from the beginning of the stocking period until harvest. Body weight was measured using an analytical balance, while total length was measured using a digital caliper. Whole-body length measurements were taken from the anterior margin of the eye to the posterior end of the telson.

Parameters and data analysis

The parameters evaluated in this study included absolute weight gain, specific growth rate (SGR), gonadosomatic index (GSI), length–weight relationship, water quality, and survival rate (SR). All quantitative data were analyzed using one-way analysis of variance (ANOVA) at a 95% confidence level using SPSS software, followed by Duncan's Multiple Range Test (DMRT) when significant differences were detected. Water quality data were analyzed descriptively.

Absolute weight

Absolute weight gain is one of the primary indicators of lobster growth performance. This parameter reflects the total increase in body weight achieved during the experimental period.

The value of absolute weight gain was calculated using the following formula (Kholis & Novita, 2021):

$$AW = Wt - W0$$

Note:
AW = Absolute weight (g)
Wt = Total final weight (g)
W0 = Initial weight (g)

Specific growth rate

Specific growth rate (SGR) represents the percentage increase in body weight per day and is used as an indicator of growth performance in aquaculture studies. This parameter allows the determination of the daily growth rate of lobsters throughout the experimental period. The SGR value was calculated using the following formula (Gustilatov *et al.,* 2024):

$$SGR\ (\%/day) = \left(\frac{(Wt - W0)}{t}\right) \times 100$$

Note:
SGR = Specific growth rate (%/day)
Wt = Total final weight (g)
W0 = Initial weight (g)
t = Rearing time (day)

The relation withinn length and weight

The length and weight relationship is an important biological parameter used to evaluate growth patterns and assess the physiological condition of aquatic organisms. This relationship is determined by the value of the growth coefficient (b) obtained from the length–weight equation. A value of b = 3 indicates isometric growth, where body weight increases proportionally with body length. A value of b>3 indicates positive allometric growth, suggesting that body weight increases at a faster rate than body length. Conversely, a value of b<3 indicates negative allometric growth, where body length increases more rapidly than body weight. It was calculated using the following equation (Mirzaei *et al.,* 2023):

$$W = a.CL^b$$

Notes:
W = Absolute weight of lobster (g)
CL = Carapace length of lobster (cm)
a and b = Constant

Gonadosomatic index

The gonadosomatic index (GSI) is a reproductive parameter commonly used to assess the degree of gonadal development and maturation in aquatic organisms. This index represents the proportion of gonad weight relative to total body weight and serves as an indicator of reproductive status. This value was calculated using the following equation (Amali & Sari, 2020):

$$GSI = \frac{Wg}{Wt} \times 100$$

Notes:
GSI = Gonadosomatic index (%)
Wg = Gonad weight (g)
Wt = Lobster weight (g)

Gonadal maturity stage

The gonadal maturity stage is one of the parameters used to analyze gonadal development in aquatic organisms. This parameter is assessed macroscopically through direct observation by comparing the morphological characteristics of lobster gonads with relevant references in the literature. The maturity stages of spiny lobster are classified into five levels. Atherley *et al.* (2021) reported that lobster gonadal maturity is categorized into Stage I, Stage II, Stage III, Stage IV, and Stage V. These stages are distinguished

Table 1. Morphological characteristics of female spiny lobster gonads based on gonadal maturity stage.

Gonadal maturity stage	Phase	Morphological characteristics
TKG I	*Immature*	- Pale white in color - Thin and small in size
TKG II	*Developing*	- Whitish to pale yellow in coloration - Thicker in size
TKG III	*Spawning capable*	- Yellow to bright orange in coloration - Larger in size
TKG IV	*Regressing*	- White in color with orange spots at the distal end

based on specific morphological characteristics of each gonadal development stage in female spiny lobsters.

Survival rate

Survival rate (SR) indicates the survival performance of cultured organisms. This parameter is used to evaluate the feasibility and effectiveness of reproductive engineering techniques applied to living organisms. A higher survival rate reflects better adaptability and lower mortality during the experimental period. The survival rate was calculated using the following formula (Paramadina *et al.,* 2025):

$$SR\ (\%) = \frac{N_t}{N_0} \times 100$$

Notes:
SR = Surival Rate (%)
Nt = Number of lobsters at final (ind)
N0 = Number of lobsters at initial (ind)

RESULTS AND DISCUSSION

Results

Absolute weight

Laserpuncture induction in spiny lobsters significantly enhanced the absolute weight gain of female individuals (Table 2). Treatment A, showed that female lobsters were subjected to a 2-second laserpuncture exposure, produced the highest mean absolute weight gain of 45 g. In contrast, the control group without induction exhibited the lowest absolute weight gain at 27 g. Treatment B, involved a 4-second laserpuncture exposure, resulted in an absolute weight gain of 38.8 g. Meanwhile, Treatment C, in which lobsters were exposed to laserpuncture for 6 seconds, produced an absolute weight gain of 32.4 g.

Specific growth rate

Female spiny lobsters in the control treatment exhibited the lowest specific growth rate (SGR) at 0.64%/day. Lobsters in Treatment B showed an SGR of 0.92%/day, while those in Treatment C recorded an SGR of 0.77%/day. Treatment A, that lobsters were subjected to a 2-second laserpuncture induction, produced the highest SGR with an average value of 1.07%/day. These results are consistent with those presented in Table 3. This indicates that laserpuncture induction can significantly enhance the growth performance of female spiny lobsters, as reflected in the absolute weight gain parameter.

Length–weight relationship

The length–weight relationship across all treatments of female spiny lobsters in this study exhibited negative allometric growth. Negative allometry indicates that the increase in body length occurs at a faster rate than the increase in body weight. This condition is occured when the value of the growth coefficient (b) is less than three. The results of this analysis are presented in Table 4.

Table 2. Absolute weight of female spiny lobster in the study.

Treatments	K	A	B	C
Maximum weight (g)	31	48	46	37
Minimum weight (g)	23	41	30	26
Average ± Stdev (g)	27^{c} ± 3.4	45^{a} ±2.92	38.8^{b} ± 6.61	32.4^{c} ± 4.4

Note: Laserpuncture induction treatments applied to female spiny lobsters with different exposure durations (K = control treatment; A = 2-second laserpuncture induction; B = 4-second laserpuncture induction; C = 6-second laserpuncture induction).

Table 3. Specific growth rate of female spiny lobster in the study.

Treatments	K	A	B	C
Maximum SGR (%/day)	0.73	1.14	1.09	0.88
Minimun SGR (%/day)	0.54	0.97	0.71	0.61
Average ± Stdev (%/day)	0.64^{c} ± 0.09	1.07^{a} ± 0.07	0.92^{b} ± 0.16	0.77^{c} ± 0.11

Note: Laserpuncture induction treatments applied to female spiny lobsters with different exposure durations (K = control treatment; A = 2-second laserpuncture induction; B = 4-second laserpuncture induction; C = 6-second laserpuncture induction).

Gonadosomatic index

Female spiny lobsters in the control treatment without induction exhibited the lowest gonadosomatic index (GSI) value of 0.55. Lobsters in Treatment B showed a GSI value of 0.64, while those in Treatment C recorded a GSI of 0.58. Treatment A, the female lobsters were subjected to a 2-second laserpuncture induction, produced the highest mean GSI value of 0.84. These results are in line in Table 5. This indicates that laserpuncture induction can significantly enhance gonadal development in female spiny lobsters, as reflected by the GSI parameter.

Gonadal maturity stage

Female spiny lobsters in the control treatment and Treatment C reached gonadal maturity Stage III in five individuals. Treatment B, in which lobsters were subjected to a 4-second laserpuncture induction, resulted in four individuals reaching Stage III and one individual reaching Stage IV. Meanwhile, Treatment A, in which lobsters were exposed to laserpuncture for 2 seconds, produced one individual at Stage III and four individuals at Stage IV. The post-treatment gonadal maturity stages are presented in Table 6. These results indicate that laserpuncture induction influences gonadal development as reflected by the gonadal maturity stage (GMS), with Treatment A showing the most pronounced shift toward advanced maturation.

Discussion

Survival rate in this study was more than 80%, indicating a very high survival level in female spiny lobsters. This result suggests that laserpuncture induction is safe to apply in this species. This finding is supported by Amiri *et al.* (2022), who stated that a high survival rate indicates low cannibalism levels in spiny lobsters. Therefore, when survival rates in a culture system are relatively high, the activity can be considered

Table 4. Length–weight relationship of female spiny lobster in the study.

HPB	K	A	B	C
B Value	2.05	1.48	2.11	2.53
Allometric	(-)	(-)	(-)	(-)

Note: Laserpuncture induction treatments applied to female spiny lobsters with different exposure durations (K = control treatment; A = 2-second laserpuncture induction; B = 4-second laserpuncture induction; C = 6-second laserpuncture induction).

Table 5. Gonadosomatic index female spiny lobsters.

Treatments	K	A	B	C
Maximum GSI	0.65	1.10	0.78	0.64
Minimum GSI	0.51	0.65	0.58	0.56
Average±Stdev	$0.55^{b} \pm 0.06$	$0.84^{a} \pm 0.17$	$0.64^{b} \pm 0.08$	$0.58^{b} \pm 0.04$

Note: Laserpuncture induction treatments applied to female spiny lobsters with different exposure durations (K = control treatment; A = 2-second laserpuncture induction; B = 4-second laserpuncture induction; C = 6-second laserpuncture induction).

Table 6. Gonadal maturity stage of female spiny lobster in the study.

Treatments	K (ind)	A (ind)	B (ind)	C (ind)
TKG I	-	-	-	-
TKG II	-	-	-	-
TKG III	5	1	4	5
TKG IV	-	4	1	-

Note: Laserpuncture induction treatments applied to female spiny lobsters with different exposure durations (K = control treatment; A = 2-second laserpuncture induction; B = 4-second laserpuncture induction; C = 6-second laserpuncture induction).

feasible for implementation. Several factors may influence survival rate (SR).

According to Kropielnicka-Kruk *et al.* (2022), these factors including adaptation, feeding, and water quality. In addition to laserpuncture treatment, the culture of female spiny lobsters requires proper management of adaptation processes, feeding regimes, and water quality. Laserpuncture treatment may influence the adaptation patterns of female lobsters; therefore, maintaining stable adaptation requires appropriate feed management and optimal water quality. Proper management of these parameters can reduce stress levels and minimize cannibalism among female spiny lobsters. The effect of laserpuncture induction on female spiny lobsters significantly influenced growth performance.

Kusuma *et al.* (2007) reported that biological stimulation induced by laserpuncture applied to the X-organ inhibits the production of molting-inhibiting hormone (MIH). This inhibition leads to increased production of growth hormone-releasing hormone (GHRH) (Kusuma & Hariani, 2017). The laserpuncture applied to the ventral region of female lobsters stimulates increased production of crustacean hyperglycemic hormone (CHH) (Shyamal *et al.,* 2018). Loredo-Ranjel *et al.* (2017) stated that the Y-organ, located in the ventral region, is a major source of CHH production in spiny lobsters. This hormone is distributed through crustacean hemolymph and is associated with increased glucose levels in the hemolymph. CHH is also related to several hormones such as cortisol, catecholamines, growth hormone (GH), glucagon, and thyroid hormones. The synergistic stimulation at these two anatomical sites enhances the growth performance of female spiny lobsters.

Isriani *et al.* (2022) stated that specific growth rate (SGR) is closely related to lobster weight gain. When absolute weight increases, SGR also increases, and vice versa. If absolute weight gain shows a significant increase after laserpuncture induction, SGR can also be considered significantly affected. This was also supported by Prastowo *et al.* (2021), whose study on spiny lobsters under different treatments demonstrated that SGR is directly proportional to absolute weight gain; thus, an increase in weight gain is accompanied by an increase in SGR. Amiri *et al.* (2022) reported that in Indonesian waters, most spiny lobsters exhibit negative allometric growth patterns. This indicates that body length increases faster than body weight. Payán-Alejo *et al.* (2025) emphasized that understanding allometry is important for assessing environmental suitability, feeding conditions, and adaptation in spiny lobsters.

In addition, Mirzaei *et al.* (2023) stated that faster length growth compared to weight growth in marine crustaceans may indicate healthy individuals in good physiological condition. These findings support the conclusion that laserpuncture induction does not alter the general growth pattern of female spiny lobsters. Among the treatments, the 2-second laserpuncture induction was the most effective, as it produced the most optimal response in stimulating growth and gonadal development compared with other treatments. Laserpuncture induction with different exposure durations significantly affected gonadal development as indicated by gonadal maturity stage (GMS). Ramandey *et al.* (2023) reported that determination of GMS in crustaceans such as spiny lobsters indicates reproductive readiness. This is essential for determining whether the organism has reached sexual maturity. By identifying these stages, reproductive development can potentially be accelerated through biotechnological interventions such as laserpuncture induction.

Haarr *et al.* (2023) also stated that reproductive readiness in lobsters is more strongly influenced by developmental stage than by carapace length, as carapace length is not a specific indicator of sexual maturity. Mantayborbir *et al.* (2022) reported that laserpuncture is effective in accelerating changes in gonadal maturity stages in aquatic organisms due to increased gonadotropin secretion, which enhances reproductive development. Changes in carapace length may also indicate unstable stress levels in spiny lobsters. Laserpuncture induction with different exposure durations also significantly affected gonadal development as reflected by the gonadosomatic index (GSI). Rijal *et al.* (2023) stated that GSI is closely related to GMS, as it quantitatively represents gonadal maturation status. Higher GSI values correspond to higher gonadal maturity stages, indicating reproductive progression in spiny lobsters.

Kaur *et al.* (2018) reported that GSI in general is influenced by seasonal variations. However, this condition may differ when organisms are subjected to reproductive engineering treatments. Furthermore, GSI is also influenced by nutritional adequacy, which supports not only growth but also reproductive requirements in aquatic organisms.

CONCLUSION

The findings of this study indicate that laserpuncture can be utilized as a novel technology to enhance growth performance and biological development in living organisms, particularly crustaceans. The acceleration of gonadal development in female spiny lobsters is optimally achieved through a 2-second laserpuncture induction using a veterinary laserpuncture device applied to both the eyestalk and ventral regions. Although laserpuncture induction has been shown to exert positive effects on both growth and gonadal development in female spiny lobsters, further research is required to evaluate potential long-term side effects that may influence reproductive development and overall growth performance in laserpuncture-treated individuals.

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