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Spawning Ethology and Egg-Substrate Preference of Bigfin Reef Squid on Rope Attractors in Coastal Indonesia

Muhammad Aras[1], Irawan Alham[2*], Syamsul Hadi[3]
[1,2]Fishing Technology Study Program, Department of Maritime Technology
[3]Fishing Port Management Study Program, Department of Maritime Technology
Corresponding Author: Irawan Alham irawan.alham@polipangkep.ac.id

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A B S T R A C T

Bigfin reef squid (Sepioteuthis lessoniana) recruitment depends on suitable spawning substrates in vulnerable coastal habitats. This study described spawning behavior and egg-substrate use on a covered polyethylene-rope attractor at Pute Anging Island, Indonesia. Direct underwater observations were conducted during 06:00–07:00 and 17:00–18:00 over 60 days. Egg deposition began on day 35 and continued to day 60, producing 16 colonies, 566 egg pods, and 1,698 recorded egg units. Spawning involved 1–4 pairs, lasted approximately 15 min, and occurred only in the morning observation window. Thirteen of 32 strands were used, mainly in shaded upper positions. The attractor was accepted as spawning habitat, although controlled replication and survival assessment are required before stock-enhancement benefits can be inferred

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INTRODUCTION

Bigfin reef squid, Sepioteuthis lessoniana, is an economically important neritic cephalopod distributed widely in tropical and subtropical Indo-Pacific coastal waters. Genetic evidence indicates that the nominal taxon may comprise a species complex, underscoring the importance of geographically explicit biological observations (Triantafillos & Adams, 2005). Its rapid growth, short life cycle, schooling behavior, and repeated use of shallow reef-associated habitats make the species both productive and locally vulnerable. Reproductive timing and maturity vary geographically among loliginid populations (Hatfield & Cadrin, 2002; Syarifuddin, 2002), while multigenerational culture and life-history studies show that S. lessoniana can mature and reproduce within a comparatively short life span (Lee et al., 1994; Ikeda et al., 2009).

Coastal squid fisheries commonly depend on wild production, while fishing activity may overlap with adult aggregation and spawning periods. Squid fisheries are globally important but are characterized by short-lived stocks whose abundance can vary rapidly with fishing pressure and environmental conditions (Arkhipkin et al., 2015). Although cephalopod abundance has increased in many ocean regions over recent decades, this broad pattern does not preclude local depletion or habitat-specific recruitment constraints (Doubleday et al., 2016). Protecting or restoring functional spawning habitat is therefore a relevant complement to conventional fishing controls.

Artificial squid attractors have been developed as a low-technology intervention intended to provide attachment surfaces for egg capsules. Indonesian trials have used bamboo, metal frames, discarded tires, drums, and rope-based structures, with varying configurations and deployment depths (Aras, 2008; Baskoro & Mustaruddin, 2007; Baskoro et al., 2011; Tulak, 2000). Studies of loliginid spawning grounds show that substrate availability, female attachment decisions, and local social interactions can influence egg-capsule deposition and spawning rate (Hanlon et al., 2004; Jantzen & Havenhand, 2003). However, simply documenting eggs on an attractor does not explain the behavioral sequence by which a structure is inspected, accepted, and repeatedly used.

This study aimed to describe the spawning ethology of S. lessoniana on a covered polyethylene-rope attractor in the waters of Pute Anging Island, Barru Regency. The specific objectives were to characterize pre-deposition behavior, quantify the observed timing and duration of spawning, determine the interval and frequency of egg attachment, map the position of egg colonies among available rope strands, and record selected egg and hatchling measurements. The study was designed as a field case study rather than a controlled experiment; accordingly, it tests the operational acceptance of the structure but does not establish causal superiority over alternative designs or estimate population-level stock enhancement. Its primary contribution is a behavior-centered description that connects pair activity with fine-scale substrate use, providing design information for future replicated trials and community-based artificial spawning habitats.

LITERATURE REVIEW

Spawning Behavior and Artificial Substrates

That behavioral gap is important because the presence of eggs on an attractor does not by itself explain why a structure was accepted. Spawning is a sequence of decisions involving approach, pair interactions, inspection of the attachment surface, body positioning, repeated capsule release, and departure. Captive observations of S. lessoniana demonstrate complex social organization and visually mediated reproductive behavior, including size-dependent alternative male tactics (Boal & Gonzalez, 1998; Iwata et al., 2005). Field observations of related loliginids likewise show that mate guarding and interactions among individuals can alter deposition behavior (Hanlon et al., 2004; Jantzen & Havenhand, 2003).

Microhabitat Selection, Temporal Activity, and Early Development

The light environment within the attractor may be especially relevant. Natural loliginid egg masses are frequently associated with complex benthic structures that offer attachment points and partial protection, and females actively position the arms and body while inserting or securing newly formed egg capsules (Hanlon et al., 2004; Jantzen & Havenhand, 2003). A covered attractor can simultaneously alter illumination, flow, distance from the seabed, and visual contrast. Consequently, an observed preference for a shaded position should be interpreted as a microhabitat association rather than as proof that light alone controls site choice.

Temporal behavior is another unresolved design consideration. If egg deposition is concentrated within a narrow daily period, observation schedules and management interventions should be aligned with that period. Conversely, occasional observations can create a false impression of strict diel timing. Detailed field studies of squid spawning show that reproductive activity is socially dynamic and can vary over short temporal scales (Hanlon et al., 2004; Jantzen & Havenhand, 2003). A defensible behavioral description must therefore report both the observed timing and the limits imposed by the sampling schedule.

The early developmental stage also determines whether an artificial spawning structure functions beyond initial attraction. Egg capsule dimensions, incubation time, hatching condition, and early hatchling size provide basic indicators of development, although these outcomes are strongly influenced by temperature, water quality, maternal effects, and handling. Indonesian reproductive observations and laboratory life-cycle studies document rapid embryonic development and a short life cycle in S. lessoniana, while classic cephalopod research emphasizes strong environmental control of incubation and early growth (Choe, 1966; Danakusumah et al., 1995; Lee et al., 1994; Ikeda et al., 2009). Developmental measurements should therefore be interpreted together with their environmental and sampling context.

METHODOLOGY

The study used a descriptive qualitative case-study design supported by experimental deployment of a squid attractor and direct underwater observation. The approach was selected because the principal variables were behavioral sequences, timing of egg attachment, pair attendance, and fine-scale position within the structure. Observers avoided capturing or physically manipulating spawning adults, consistent with broader recommendations to minimize disturbance and apply precautionary welfare principles in cephalopod research (Moltschaniwskyj et al., 2007; Fiorito et al., 2015). Quantitative summaries were used to describe frequency, duration, substrate utilization, egg accumulation, and early development; the design was not intended to estimate population-scale effects.

Study Area and Observation Period

Fieldwork was conducted in the coastal waters of Pute Anging Island, Barru Regency, South Sulawesi Province, Indonesia. The seabed at the deployment area consisted predominantly of sand and coral material and was located near coral-reef and seagrass habitats. Water clarity was described as high during field operations. The local current was relatively weak, not exceeding approximately 0.5 knot during the reported observations, and the seabed sloped gradually through a depth range of approximately 3–7 m. The attractor was positioned at 3–4 m depth. The precise geographic coordinates, deployment year, and complete calendar dates were not recorded in the available field documentation and should be supplied before journal submission.

Observations extended for 60 days. The documentation indicates that the first egg attachment was identified on day 35 after deployment and the final new attachment on day 60, with the field period spanning months reported as October to December. Because exact deployment and retrieval dates were unavailable, chronology was standardized to days after deployment. This avoids assigning calendar dates that cannot be verified while retaining all temporal information recorded by the field team.

Rope-Attractor Design and Construction

The attractor had a box-shaped frame supported by buoyant and weighted components. Its principal frame was constructed from polyethylene rope. Vertical members used 12-mm-diameter rope to resist tension, while horizontal members used 10- and 8-mm-diameter rope. The upper frame incorporated sealed 1-inch polyvinyl chloride pipe as auxiliary buoyancy. A lower polyvinyl chloride component was also reported, but its diameter was not specified. The overall external length, width, and height of the attractor were not recorded.

A black rubber sheet covered the upper surface to create a shaded internal space. The sheet dimensions were not reported. Egg-attachment substrates consisted of 32 polyethylene rope strands per attractor, each 10 mm in diameter and 35 cm long. Four reinforced concrete weights, each weighing approximately 3,000–4,000 g, held the frame near the seabed, and a 10-kg sand anchor provided additional stabilization. These construction details are summarized in Table 1.

Rope, pipe, cover, and weight combinations have been used in Indonesian squid-attractor development because they can create protected internal spaces while providing flexible suspended attachment surfaces (Baskoro & Mustaruddin, 2007; Baskoro et al., 2011).

Deployment Procedure

The attractor was installed manually by divers at 3–4 m depth. Units were reportedly arranged in a line and connected with rope at 1-m intervals. The available documentation does not state the total number of units, so the unit count cannot be used as an analytical denominator. Divers inspected the structures immediately after setting to ensure an upright orientation and adequate stability under the prevailing current. Earlier work in the same locality had shown that shallow-water attractors could receive squid eggs, while other Indonesian studies identified deployment depth and substrate type as relevant design variables (Aras, 2008; Tallo, 2006).

Underwater Behavioral Observations

Direct underwater visual observations were conducted during two daily windows: 06:00–07:00 and 17:00–18:00 Central Indonesia Time. Divers used standard underwater observation equipment, a waterproof light, and digital documentation. The frequency of dives and total observation hours were not recorded, preventing calculation of sighting rates per unit effort. Behavioral records focused on the number of attending pairs, approach and inspection behavior, movement relative to the current, duration of a deposition bout, interval between successive attachments, and departure from the structure.

The observation protocol distinguished a pre-deposition phase from active deposition. The pre-deposition phase included group arrival, circling or directional movement, pausing, and female inspection of the rope substrate. Active deposition began when the female positioned herself at a rope strand and attached an egg pod while a male remained nearby. A deposition bout ended when the pair ceased attachment and departed from the immediate attractor space. Similar behavioral partitioning has been used to describe structured interactions and egg-capsule deposition in loliginid spawning aggregations (Hanlon et al., 2004; Jantzen & Havenhand, 2003).

Egg-Colony Mapping and Developmental Measurements

Each of the 32 rope strands was treated as a potential attachment substrate. Used strands were counted, and the location of colonies was categorized according to their position within the attractor. The original record reported 13 used strands and labeled utilization as 46.6%. Direct recalculation gives $13/32 \times 100 = 40.625\%$; therefore, the corrected utilization rate of 40.6% is reported throughout this manuscript. Colony accumulation was recorded as 16 colonies, 566 egg pods, and 1,698 individual egg units as defined in the field notes. Because the source terminology alternated among pods, capsules, and egg units, all three values are retained without redefining the biological unit.

Egg development was assessed from a sample observed at 14 days. Pod length and diameter were measured, incubation time to hatching was recorded, and newly hatched squid were measured on day 0 and day 1. Post-hatching observations extended from 1 to 72 h, but no denominator or mortality count was available; therefore, a survival percentage was not calculated.

Data Analysis

Observations were tabulated chronologically and analyzed descriptively. Behavioral sequences were synthesized from repeated field notes, and numerical summaries were calculated for deposition timing, frequency, substrate use, egg accumulation, and early growth. No hypothesis tests were performed. Interpretations were compared with established descriptions of squid reproductive behavior, artificial spawning substrates, and early cephalopod development (Choe, 1966; Hanlon et al., 2004; Baskoro et al., 2011). Statements concerning shade preference, predator avoidance, or tactile stimulation are treated as behavioral interpretations rather than experimentally isolated mechanisms.

Table 1. Reported construction specifications of the rope attractor.

Component	Reported specification	Data-quality note
Overall frame	Box-shaped polyethylene-rope frame	External length, width, and height not reported
Vertical frame rope	12 mm diameter	Reported
Horizontal frame rope	10 mm and 8 mm diameter	Reported
Upper buoyancy	Sealed 1-inch PVC pipe	Reported
Lower PVC component	Diameter not reported	Incomplete specification
Upper cover	Black rubber sheet	Sheet dimensions not reported
Attachment substrate	32 PE rope strands; 10 mm diameter; 35 cm long	Reported per attractor
Concrete weights	4 units; 3,000–4,000 g each	Reported
Sand anchor	10 kg	Reported
Deployment depth	3–4 m	Reported
Inter-unit spacing	1 m	Total number of units not reported

Table 2. Observation windows, behavioral endpoints, and analytical treatment.

Observation element	Protocol or variable	Analytical treatment
Morning observation	06:00–07:00 Central Indonesia Time	Direct visual description
Evening observation	17:00–18:00 Central Indonesia Time	Direct visual description
Behavior	Pair number, approach, inspection, positioning, deposition, departure	Chronological synthesis
Deposition timing	Bout duration and interval between attachments	Descriptive range
Substrate use	Number and position of used rope strands	Used strands / 32 × 100

Observation element	Protocol or variable	Analytical treatment
Egg accumulation	Colonies, pods, and recorded egg units	Totals and descriptive averages
Development	Pod dimensions, incubation, hatchling length	Descriptive measurements

RESEARCH RESULT

Attractor Stability and Internal Habitat

The box-shaped rope attractor remained upright and stable at the deployment site under currents reported to be no greater than approximately 0.5 knot. The combination of sealed upper polyvinyl chloride pipe, concrete weights, and a 10-kg sand anchor maintained the suspended frame near the seabed. Divers did not report collapse, overturning, or substantial displacement during the 60-day observation period. The 1-m spacing between connected units provided open water around each structure, although the number of installed units was not documented.

The black rubber cover produced a visibly shaded zone beneath the upper frame. This zone contrasted with the more illuminated outer and lower sections of the structure. The 32 flexible rope strands hung into the interior and remained available as attachment points. No quantitative measurements of irradiance, turbidity, or current velocity within the structure were made, so the internal microhabitat was characterized visually rather than instrumentally.

Pre-Spawning Attendance and Substrate Inspection

Squid approached the attractor in small reproductive groups consisting of 1–4 pairs. Initial attendance did not always lead directly to egg deposition. The interval between apparent site inspection and a subsequent return for spawning ranged from 3 to 14 days. During approach, individuals moved with the prevailing current or circled the structure before pausing near the interior. The field notes described coordinated movements between the female and an accompanying male, with the male remaining close while the female moved toward the attachment strands.

Female inspection preceded deposition. The female advanced and withdrew repeatedly and contacted or closely examined the rope before selecting a position. The pair then established a relatively stable orientation within the upper interior of the attractor. This repeated forward-and-back movement continued through the spawning bout and was synchronized with successive attachment events. Although the observations did not isolate sensory mechanisms, the sequence was consistent with active assessment of the attachment surface rather than random release of eggs.

Duration and Fine-Scale Pattern of Egg Deposition

An observed spawning bout lasted approximately 15 min. Within a bout, successive egg-pod attachments occurred at intervals of approximately 10–30 s. Several pairs could be present and deposit eggs during the same morning observation period. The male remained in attendance near the female during substrate inspection and deposition, but copulation itself was not documented during the observation windows.

The recorded behavior followed a repeatable sequence: entry into the attractor area, circling or current-oriented movement, temporary pausing, female inspection, pair positioning, repeated attachment, and departure. The short interval between attachments accounted for the rapid accumulation of pods during a single bout. No aggressive contact, physical interference, or displacement among pairs was documented, although the observational design was not intended to quantify social competition.

Diel Timing and Spawning Frequency

All directly observed egg-attachment events occurred during the 06:00–07:00 morning window. No pairs were recorded at the attractor during the 17:00–18:00 evening window. In the afternoon and evening, squid were reported near reef habitat to the north of the deployment site, where they appeared to be engaged in feeding-related activity. Because observations did not cover the remaining 22 h of the day, the findings demonstrate a morning concentration within the sampled windows but do not establish that spawning was absent at all other times.

The first egg deposition was detected on day 35 after attractor deployment. New deposition continued intermittently until day 60, when the last attachment was recorded. The mean interval between deposition episodes was approximately 3–4 days. Thus, the attractor was not used immediately after deployment; instead, a 35-day colonization or discovery period preceded the first recorded spawning event, followed by recurrent use over the next 25 days.

Egg Accumulation

Across the 60-day monitoring period, 16 egg colonies accumulated on the attractor system. The field records counted 566 egg pods and 1,698 individual egg units. These totals correspond to an average of 35.4 pods and 106.1 recorded egg units per colony, although colony size was not reported separately and may have been highly variable. The overall ratio was 3.0 recorded egg units per pod. Egg accumulation was spatially clustered rather than evenly distributed. Repeated use of the same upper interior region caused colonies to hang in groups. No eggs were reported on the external upper cover, the concrete weights, the anchor, or the lower frame. The concentration of colonies on selected strands indicated that availability alone did not determine use.

Rope-Strand Utilization and Position Preference

Of 32 available rope strands, 13 received eggs. The corrected substrate-utilization rate was therefore 40.6%. Nineteen strands, or 59.4%, remained unused. Egg colonies were concentrated on the upper portions of the used strands directly beneath the black rubber cover. The lower portions and more exposed positions were used less or not at all according to the field notes.

This distribution demonstrates a clear positional association between egg attachment and the shaded upper interior. However, the design did not independently manipulate shade, strand height, flow, or proximity to the frame.

Accordingly, the observed pattern identifies a preferred micro-position within this attractor configuration but cannot determine which individual physical variable caused the selection.

Egg-Pod Characteristics, Incubation, and Hatching

The egg pods were translucent white and surrounded by a gelatinous protective layer. At 14 days, sampled pods averaged 64 mm in length and 13 mm in diameter. Complete incubation to hatching required 28 days under the field conditions. Hatched pods were recognizable by an opening in the envelope and a collapsed or deflated appearance.

Newly hatched squid measured an average of 7.7 mm on day 0 and 9.7 mm on day 1. The absolute increase was 2.0 mm, equivalent to 26.0% relative to the day-0 length. This apparent one-day change should be interpreted cautiously because sample size, repeated measurement of the same individuals, and measurement uncertainty were not documented. Hatchlings were observed for 1–72 h, but survival could not be expressed quantitatively because the number stocked and the number remaining alive were not recorded.

Consolidated Quantitative Outcomes

Table 3 summarizes the principal behavioral and reproductive outcomes. The attractor was first used after 35 days, received recurrent deposition every 3–4 days, and accumulated 16 colonies by day 60. Active deposition involved 1–4 pairs and lasted about 15 min, with 10–30 s between attachments. Forty-point-six percent of available strands were used, specifically in the shaded upper interior. Table 4 summarizes egg and hatchling measurements, including the 28-day incubation period, 64 × 13 mm pod dimensions at day 14, and hatchling lengths of 7.7 and 9.7 mm on days 0 and 1, respectively.

Table 3. Principal spawning-behavior and substrate-use observations.

Variable	Observed value
Monitoring duration	60 days
First detected egg deposition	Day 35 after deployment
Last detected new deposition	Day 60 after deployment
Interval between deposition episodes	3–4 days
Observed daily spawning window	06:00–07:00
Pairs attending an event	1–4 pairs
Approximate spawning-bout duration	15 min
Interval between successive attachments	10–30 s
Total egg colonies	16
Total egg pods	566
Total recorded egg units	1,698
Available rope strands	32
Used rope strands	13
Corrected strand utilization	40.6%

Variable	Observed value
Preferred position	Upper rope sections beneath the black cover

Table 4. Egg-pod development and hatchling measurements.

Developmental metric	Reported value	Interpretive constraint
Egg-pod appearance	Translucent white with gelatinous layer	Qualitative field description
Age at pod measurement	14 days	Sample size not reported
Mean pod length	64 mm	Measurement uncertainty not reported
Mean pod diameter	13 mm	Measurement uncertainty not reported
Incubation to hatching	28 days	Temperature series unavailable
Mean hatchling length, day 0	7.7 mm	Sample size not reported
Mean hatchling length, day 1	9.7 mm	Repeated-measure status unknown
Post-hatching observation	1–72 h	Survival percentage not calculable

DISCUSSION

Acceptance of the Rope Attractor as a Spawning Substrate

The central finding is that S. lessoniana repeatedly accepted the covered polyethylene-rope structure for egg deposition. Acceptance was demonstrated by recurrent spawning after the initial 35-day delay, continued use until day 60, and accumulation of 16 colonies. This pattern is consistent with Indonesian attractor trials and with broader loliginid evidence that females repeatedly use suitable attachment structures within spawning grounds (Aras, 2008; Hanlon et al., 2004; Jantzen & Havenhand, 2003). The result therefore supports the biological plausibility of rope attractors as artificial egg-attachment habitat, although it does not by itself establish population enhancement.

The 35-day delay before first deposition is operationally important. A newly deployed structure may require time for squid to encounter it, inspect it repeatedly, or accept changes in fouling, odor, or visual contrast. The observed 3–14-day interval between inspection and return supports the possibility that site acceptance can involve repeated assessment rather than an immediate response. Because deposition rates on natural spawning grounds are influenced by both social interactions and local substrate conditions (Hanlon et al., 2004), short deployments could underestimate attractor performance and should not be interpreted as evidence of failure.

Pair Coordination and Deposition Rhythm

The sequence of female inspection, male attendance, synchronized positioning, and repeated attachment indicates that spawning on the attractor was a coordinated pair activity. Complex social recognition and reproductive signaling have been documented in S. lessoniana, while male tactics can vary with relative body size (Boal & Gonzalez, 1998; Iwata et al., 2005). Similar organization has been reported on loliginid spawning grounds, where courtship, mate guarding, and social interference influence spawning rate and female deposition behavior (Hanlon et al., 2004; Jantzen & Havenhand, 2003). The present observations extend that behavioral framework to a rope-based artificial substrate in shallow Indonesian waters.

The 10–30 s interval between successive attachments and the approximately 15-min bout duration provide fine-scale design information. The upper interior must permit repeated forward movement and withdrawal while keeping the female close enough to the strand to secure each pod. Flexible 10-mm rope may support this sequence by providing a graspable, slightly mobile surface. Yet tactile stimulation was not measured directly, and the study did not compare rope diameter, texture, stiffness, or material. Future experiments should randomize these features within the same attractor so that selection can be attributed to specific substrate properties.

Morning Concentration of Spawning Activity

Egg attachment was observed during the 06:00–07:00 window and not during the 17:00–18:00 window. A shaded dawn environment may reduce exposure while squid are occupied with spawning and may create a visual transition similar to protected reef crevices. Reproductive activity in loliginid squids is behaviorally flexible and strongly shaped by interactions on the spawning ground (Hanlon et al., 2004; Jantzen & Havenhand, 2003). The morning concentration observed here is therefore biologically plausible, but it should be treated as a pattern within the sampled periods rather than as proof of an obligate dawn-spawning rhythm.

Nevertheless, the diel conclusion must remain bounded by the sampling design. Only two one-hour periods were observed, and there was no continuous video or nocturnal monitoring. The results therefore establish morning use relative to the sampled evening period, not exclusive spawning at dawn. This distinction is essential because a narrow observation schedule can transform a sampling pattern into an apparent biological rule. Continuous recording over several 24-h cycles, combined with measurements of underwater irradiance, current, and predator presence, would test whether the morning pattern reflects true behavioral periodicity.

Selection of the Shaded Upper Interior

The strongest spatial pattern was concentration of eggs on the upper rope sections beneath the black cover. Thirteen of 32 strands were used, giving a corrected utilization rate of 40.6%, while 59.4% remained unused. This selective distribution is compatible with the broader understanding that female loliginids actively choose attachment positions and that egg deposition is not spatially random within spawning habitat (Hanlon et al., 2004; Jantzen & Havenhand, 2003). The result suggests that internal geometry and microhabitat should be treated as design variables rather than assuming that all available strands are functionally equivalent.

The covered upper interior may combine several favorable conditions: reduced illumination, proximity to a stable frame, limited contact with the seabed, and sufficient circulation to ventilate hanging egg clusters. These variables were confounded in the present design. The term "negative phototaxis" would therefore overstate the evidence, because individual responses to a controlled light gradient were not tested. The defensible interpretation is positional preference for a shaded upper microhabitat within the specific attractor. A factorial design manipulating cover, strand height, and flow exposure would clarify the mechanism.

The corrected percentage also illustrates the importance of arithmetic validation during manuscript preparation. The original field summary reported 46.6%, but 13 used strands divided by 32 available strands equals 40.6%. Correcting this value does not change the biological conclusion—use was selective—but it materially improves quantitative integrity.

Egg Development and Early Hatchlings

The 28-day incubation period and the presence of intact, translucent gelatinous pods indicate that development proceeded to hatching on the artificial substrate. Classic cephalopod studies show that incubation and hatchling condition vary with species and environmental conditions, particularly temperature (Choe, 1966). Studies of S. lessoniana cultured through multiple generations and observed across complete life cycles likewise demonstrate rapid development but substantial plasticity in growth, maturation, and longevity (Lee et al., 1994; Ikeda et al., 2009). The observed incubation period is therefore plausible, but direct comparison among studies requires concurrent temperature and water-quality measurements.

Hatchlings averaged 7.7 mm on day 0 and 9.7 mm on day 1. Because the sample size and measurement protocol were not documented, the apparent 26.0% increase should not be interpreted as a verified daily growth rate. The more reliable conclusion is that hatchlings emerged at a measurable size and remained available for observation during the first 72 h. Early survival was described as limited, but a survival rate cannot be calculated without counts of initial and surviving individuals. This highlights a major transition between providing a spawning surface and achieving stock enhancement: egg deposition and hatching are necessary, but they do not demonstrate successful recruitment.

Implications for Artificial Spawning Habitat

The results support the practical use of covered rope structures as candidate artificial spawning habitat in shallow coastal waters. The materials are simple, the structure remained stable, and squid repeatedly used selected rope strands. For community deployment, design priority should be given to structural stability, shaded internal attachment surfaces, adequate water circulation, and protection from fishing disturbance. This habitat-oriented intervention is relevant because squid support major fisheries worldwide and their short life cycles couple annual recruitment closely to environmental and spawning conditions (Arkhipkin et al., 2015).

Mass deployment should not, however, be presented as proven stock enhancement based on a single descriptive case. Population benefit depends on additional processes: attraction must not merely concentrate adults for easier capture; eggs must survive predation, fouling, and physical disturbance; hatchlings must recruit successfully; and fishing mortality must remain compatible with replacement. Broad increases in cephalopod abundance reported at global scales do not eliminate the need for local, species-specific management and habitat evaluation (Doubleday et al., 2016). Attractors should therefore be embedded within monitored no-take or restricted-use spawning zones rather than deployed as isolated fishing aids.

CONCLUSIONS AND RECOMMENDATIONS

The covered polyethylene-rope attractor was repeatedly used by bigfin reef squid as an egg-deposition substrate in the shallow waters of Pute Anging Island. Spawning was first detected 35 days after deployment and continued until day 60, producing 16 colonies, 566 egg pods, and 1,698 recorded egg units. Observed bouts involved 1–4 pairs, lasted approximately 15 min, and included attachments at 10–30 s intervals. New deposition occurred every 3–4 days and was concentrated in the 06:00–07:00 observation window. Spatial use was selective: 13 of 32 rope strands were occupied, giving a corrected utilization rate of 40.6%, and colonies clustered on upper strands beneath the black cover. Eggs developed to hatching over 28 days, with pods averaging 64 mm by 13 mm at day 14 and hatchlings averaging 7.7 mm on emergence. These observations add behavior-level evidence that shade, elevation within the structure, and flexible rope surfaces are relevant design attributes for artificial squid spawning habitat. The findings do not yet demonstrate population enhancement because the study lacked controls, replication, continuous diel monitoring, and quantified hatching or post-hatching survival. Future work should experimentally separate the effects of shade, substrate texture, depth, and flow, while measuring egg survival and recruitment relative to natural spawning sites. Deployment programs should also protect attractor areas from fishing so that the structures do not function as aggregation devices that increase adult vulnerability.

For practical implementation, covered rope attractors should be placed within monitored or restricted-use spawning areas, maintained for structural stability, and evaluated using standardized indicators of egg survival, hatching success, and recruitment.

ADVANCED RESEARCH

The study provides rare direct behavioral observations, but its inferential scope is constrained by missing replication, no control treatment, incomplete observation effort, and absent environmental time series. The number of attractor units, exact coordinates, total dive hours, deployment dates, temperature, salinity, dissolved oxygen, turbidity, and illumination were not documented in the available record. These limitations prevent estimation of encounter probability, treatment effects, hatching success, and population benefit. Future work should also report procedures for minimizing observer disturbance and handling risk in accordance with established cephalopod research-welfare guidance (Moltschaniwskyj et al., 2007; Fiorito et al., 2015).

A stronger follow-up experiment should compare covered and uncovered attractors, multiple rope materials and diameters, upper versus lower strand positions, and at least three depth strata. Replicate units should be randomly assigned, monitored continuously by camera, and evaluated using egg counts standardized by available substrate area and observation effort. Temperature, salinity, current speed, irradiance, fouling, predation, and hatching success should be measured concurrently. Genetic or morphological verification is also advisable because S. lessoniana has been shown to represent a species complex in parts of its range (Triantafillos & Adams, 2005). Such a design would distinguish attraction, substrate preference, developmental success, and true stock-enhancement potential.

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