Fisheries and Aquatic Sciences
Indexed in SCOPUS and KCI
eISSN : 2234-1757

Journal Title:	Fisheries and Aquatic Sciences
Manuscript ID:	fas-2022-0089
Degree (Date created):	1st (2022-08-15)
Manuscript Title:	Behavioral Response of Purpleback Flying Squid Sthenoteuthis oualaniensis (Mollusk; Cephalopod) to the Flashlight Artificial Bait Colors
Running Title:	Effect of bait color on squid's feeding rate
Urgency:	Normal Manuscript
Type:	Research Article
Category:	Ecology and Fisheries Resource Management;

Fisheries and Aquatic Sciences
Address: Pukyong National University, 45 Yongso-ro, Nam-gu, Busan 48513, Korea
Tel: +82-51-629-7363,
Email: kosfas@kosfas.or.kr
Homepage: http://www.e-fas.org/

Behavioral Response of Purpleback Flying Squid *Sthenoteuthis oualaniensis* (Mollusk; Cephalopod) to the Flashlight Artificial Bait Colors

Silvester B. Pratasik[1)], Lefrand Manoppo[2)], Effendi P. Sitanggang[2)], Lusia Manu[2)]

[1)]Fisheries Resources Management, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Jl. Kampus Bahu Manado-95115, North Sulawesi, Indonesia; [2)]Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Jl. Kampus Bahu Manado-95115, North Sulawesi, Indonesia. Corresponding author: S.B. Pratasik, spjong07@yahoo.com

ABSTRACT. This study aimed to the response of deep-sea squid *Sthenoteuthis oualaniensis* to the light colors of the artificial bait. This experiment used the commercial artificial flashlight baits commonly sold in the fishing shop. The bait has several different light color combinations. The light colors were modified into several light colors by inactivating certain colors and used as treatments. We applied red-green, green, blue, and commercial bait lights in this study. Each treatment has 3 replications. The effect was expressed as the amount of squid caught. Data were analyzed by One-Way ANOVA. Results showed a significant effect on the number of squid catches. There was significantly different squid catches among the treatments. It indicates that this artificial flashlight bait could be developed to maximize squid catches.

Keywords: commercial jig, modification, effect, catch.

Introduction

The exploitation of fisheries resources starts from a basic human need to obtain animal protein sources. Squid is one of the protein sources from the ocean, and nearly all body parts are edible. Since 1950, capture production of cephalopods has continued to grow (Hunsicker et al., 2010; Doubleday et al., 2016), with total commercial annual catches between 3.5 and 4.9 million tons in 2008–2017 (FAO, 2019), almost 4.6 times higher than that of the 1950s. Cephalopods on average support approximately 15 and 20% of marine fishery landings and landed values, respectively (Hunsicker et al., 2010; FAO, 2019). This group has unique life history characteristics, including rapid growth, short lifespan, and semelparous reproductive strategy, giving them both sensitivity and resilience to anthropogenic exploitation and oceanographic variability (Rodhouse et al., 2014). The species within the family Ommastrephidae support approximately 33.8% of the global cephalopod's landings (FAO, 2019). This group is recognized as voracious and adaptable predators of a broad range of prey including small crustaceans and fishes at early life stages and shift to micronekton, larger fishes, and cephalopods (including cannibalism) as they grow (Nigmatullin et al., 2001; Alegre et al., 2014). Despite its economic importance, the offshore oceanic squid resources' exploitation rate is relatively low (Worms, 1983). The flying squids (Ommastrephidae; Oegopsid) cover about 65% of the world's commercial cephalopods (Roper et al. 1984; Brunetti 1990) with a total of about 2.6 million in 1991 (FAO 1993). The flying squids *Sthenoteuthis oualaniensis* (Lesson) and *Ommastrephes bratamii* are the oceanic species of this family that are distributed from the Indo-Pacific to the

Indian Ocean. According to Voss (1973), the potential of the purpleback flying squids in the Central Eastern Pacific is at least 100,000 metric tons. This species is caught commercially in the eastern and southern East China Sea, Taiwan to Okinawa by hook and line with light at night (Yoshikawa 1978; Okutani 1980; Tung 1981,). The deep-sea squids caught by traditional fishermen of Manado Bay, North Sulawesi, in the Sulawesi Sea have been identified as a dwarf form of *Sthenoteuthis oualaniensis* (Pratasik et al., 2022). These species are highly migratory and undertake diel vertical migrations of several hundred meters and seasonal migrations between the shelf and open ocean (Gilly et al., 2006; Stewart et al., 2013) so that they can act as important linkages between both neritic and oceanic food webs (Arkhipkin, 2013).

There are numerous studies on bait types to find the highest catch, from fish and shrimp flesh, live bait, and artificial bait. Fish and **s**quids were observed to be attracted to squid jigging vessels due to the phototaxis [Rao. 1996]. It is related to their behavior to avoid predators or to enhance feeding efficiency (Solomon and Ahmed, 2016), and their response depends upon species, ontogenic development, characteristics of the light source, intensity, color, and wavelength (Mallawa et al., 1991). Therefore, fishermen catch squid using light that illuminates in water as well as jigs to attract the squids to aggregate and bite the jigs (Asokan and Krishnan, 2021). It relies on the artificial bait of shrimp-like siliconized jig fishing (Altinagac, 2006; Ulas & Aydin, 2011; Paighambari et al., 2012; Reza et al., 2019**;** Aydin & Ilkyaz, 2021**).** Other studies on hand-line fishing are also done using different colors of shrimp-shaped jigs (Altinagac, 2006; Ulas & Aydin, 2011; Paighambari et al., 2012; Aydin & Ilkyaz, 2021). Squid fishing in North Sulawesi is done by traditional fishermen using 5 to 7 M-boat. The traditional fishermen of Manado Bay, North Sulawesi, catch the deep-sea squid *S. oualaniensis* using a mini-battery-supported flashlight artificial bait sold in the fishing stores. The flashlight artificial bait contains several different alternately blinking light colors to get the squid to bite. This study modifies the light colors to find the best modification of light color against the catches.

Method

This study was carried out from June to July 2020. Traditional fisheries catch deep-sea *squids S. oualaniensis* in the Sulawesi Sea, North Sulawesi, at night (Figure 1). The flashlight bait is facilitated with a mini-battery to be able to produce several different light colors to attract the squid.

This experiment modified the standard commercial flashlight bait sold in the fishing shop to produce different light colors: Red-Green, Blue, Green, and Red. These different light colors were used in 10 fishing trips. Twelve skillful fishermen were used in this experiment in which they were divided into 4 groups of 3 people to operate each light color. The common commercial flashlight bait was also used as a control treatment. Each line used only one jig and all jig fishing activities were carried out at the same time.

Figure 1. Sampling site.

The use of the red-colored bait was eventually terminated because it was always cut off and lost. The experiment utilized only commercial bait, red-green bait, blue bait, and green bait as treatment with 3 replications represented by 3 local skillful fishermen for each bait light color. Data collections were squid catches. The catch data were analyzed with ANOVA facilitated with statistical software for comparisons. The difference between treatments was then tested using Tukey's Honestly Significant Difference (HSD) procedure.

Results

This study caught a total of 30,687 squids *S. oualaniensis* during the fishing experiment in the Sulawesi Sea, North Sulawesi. Different light color applications highly significantly influenced the number of squid catches ($P<0.001$). Analysis of Variance demonstrates that both trip and bait light color influence the squid catches (Table 1).

Table 1. ANOVA on the effect of artificial bait light colors on the number of catches.

Tukey's Honestly Significant Difference (HSD) test revealed that *S. oualaniensis* differently responded to the bait's light colors. All treatment applications gave a significantly different number of catches. Comparisons between treatments showed that all bait light color modifications gave a higher number of catches than the commercial one (Table 2).

Table 2. Multiple comparisons between treatment applications.

The significantly different squid catches are also indicated by the mean number of squid catches (Figure 1). The green-lighted jig yielded the highest mean squid catches, 377.37 (39.46%), followed by blue light color, 268.3 (28.06%), then red-green, 213.43 (22.32%), and the lowest catches in the commercial artificial bait, 97.13 (10.16%) (Figure 2 and Table 2). Multiple comparisons between treatment applications yielded 6 pairs of comparisons and indicated that all treatment flashlight jig colors yielded significantly different squid catches, in which single light colors also give the squid a higher response to taking the lure (Table 2).

Figure 2. Mean catch of squid *S. oualaniensis* during the study.

Discussion

Jigging is an essential fishing method to exploit squids selectively and avoid overexploiting to conserve resources and energy (Asokan & Krishnan, 2021). It helps to adjust operational depth according to the concentration depth of squids. They are attracted to lights and fast-moving bait or any bait-like object. A typical jig consists of a shrimp or stalk-like body made of flexible plastic with one to three hooks or more sharp barbless steel hooks at the end. Other jigs are facilitated with the mini battery-supported light blinking.

Squids are known as color-blinded animals, but the degree of contrast is important for squid behavior to attack the jig (Flores et al., 1978). The use of a flashlight jig, in fact, gave a stronger degree of contrast in the water column at night fishing than the use of light above the water and could give a stronger stimulus to the squid to attack blinking light. The flashlight jig also has a higher degree of contrast than the shrimp-like siliconized jig so that the squid more sensitively responds to the flashlight jig color in the water column. The flashlight jig could stimulate the purpleback flying squid to get the bait. On the other hand, cephalopods (squid, cuttlefish, and octopus) are well known as voracious predators of many preys, such as fish and crustaceans, or even have cannibalism behavior, so the contrast moving object in the water column could indicate the presence of moving prey.

Furthermore, the present study revealed that the modified light colors of the artificial bait caught a higher number of deep-sea squid *S. oualaniensis* in the Sulawesi Sea than the common commercial artificial bait sold in the fishing store with a combination of several different colors. There was also a significantly different effect of all light color modifications on the squid catches with the highest catch in the green light. The low attacking preference of the purpleback flying squid to the multiple light colors could result from the squid's perception of the blinking multiple colors of the flashlight bait as the aposematic coloration of the prey, in which the animal shows the unpalatability or toxicity through warning coloration. This defense mechanism is widely discussed by Endler (1978), Mappes et al (2005), Mochida et al (2015), Stevens (2007), and Toledo & Haddad (2009). Aposematism is commonly found across the animal kingdom as a defense mechanism, and it could either be chemicals, such as toxins, harmful secretions, and venoms, or physical defense, such as spines, bites, and stings (Mappes *et al.*, 2005).

This finding is in agreement with Altinagac (2006) and Paighambari et al (2012) that the green bait color is more efficient in squid jig fishing even though it does not have a significantly different effect from the use of red color in Turkish waters (Altinagac 2006) and the blue color (Paighambari et al., 2012) on the catch rate of purpleback flying squids in Iranian waters of the Oman Sea. The sensitivity of fish and some of their food animals to blue and green colors is higher because of the long wavelengths that make them penetrate deeper into the water column (Solomon & Ahmed 2016). Nevertheless, Ulaş and Aydin (2012) found the red jig is the most efficient in squid *Loligo vulgaris* Lamarck (1798) fishing in the Middle Eastern Coast of Aegean Sea, Turkey. All those findings were obtained using the shrimp-like siliconized bait.

This fishing experiment reconfirms the previous finding concerning the most efficient bait color and shows that the use of single bait light color yielded higher catches than that of multiple colors ($P<0.05$). The local fishermen of North Sulawesi commonly use the shrimp-like siliconized jig to fish shallow water squids *Sepioteuthis lessoniana.* This study did not use the red light color as a treatment, since the red-lighted bait was always taken and cut off. Therefore, we had to use a wireline to the bait to know what causes the loss and found that the red light color was taken by the cutlassfish *Trichiurus* sp. The difference in squid's preference for jig color could result from environmental conditions with locality, such as predator-prey interactions that may alter the feeding behavior on-site, and species. The presence of a higher level of the predator, such as cutlassfish *Trichiurus* sp, particularly in Sulawesi waters which is also attracted to the red-light jig has diminished the chance of the deep-sea squids *S. oualaniensis* to take the red jig.

According to Asokan and Krishnan (2021), the efficiency of squid jigging is influenced by jig structure, jigging motion, light intensity, sea state, and sea surface temperature (Cabanellas-Reboredo et al., 2012; Roberts and Sauer, 1994; Yu et al., 2015), wind speed, moon phase, and atmospheric pressure (Cabanellas-Reboredo et al., 2012), sea surface height anomaly (Yu et al., 2015), turbidity (Roberts and Sauer, 1994), chlorophyll (Hurst et al., 2012), salinity (Yu et al., 2015), and large scale climate predictors, such as the Southern Oscillation Index (SOI) and the North Atlantic Oscillation (NAO) (Roberts and Sauer, 1994; Morales-Bojorquez et al. 2001; Pierce et al., 2006). etc. These factors will influence the catches, recruitment, migration (Koopman et al (2018), and distribution of the squids. During squid jigging with lights, the quality of light (e.g. wavelength), the quantity of light (e.g. power), and the arrangement of fishing lights affect the squid attraction. These factors create underwater irradiance levels and distribution influenced by the optical characteristics of seawater, and it influences squid behavior during fishing (Arakawa et al., 1998; Yamashita et al., 2012). This experiment focused only on the effect of different jig light colors on the squid bites since the fishing was conducted in a single lunar cycle with different tide conditions. The jiggers took advantage of wind or current direction to position their boats in certain areas to avoid being drifted too far out of the mainland due to the use of the small boat (approximately 5-7 M long).

These findings showed that all light color modifications of the multiple flashlight-squid baits have contributed to the artificial squid flashlight bait development concerning the squid fishing effectivity. Light colors also influenced the feeding behavior of *S. oualaniensis*, and the single color gave a higher response of the squid to getting the lure than the multiple colors. The highest squid catch was recorded in the green light color and the lowest in the commercial artificial bait. Therefore, the present study has contributed to the development of mini-battery-supported artificial bait for effective exploitation to maximize squid production. More studies on squid feeding behavior are needed for future squid population sustainability.

Competing Interests

This article has no competing interests.

Acknowledgments

We would greatly appreciate the Rector of Sam Ratulangi University and the Dean of the Faculty of Fisheries and Marine Sciences who provided a small research grant. High appreciation is also addressed to Mr. Ponny Telleng who led the local fishermen of Manado Bay in fishing operations.

References

Altinagac U. Effect of jigs color on catching efficiency in squid fishing in Turkey. Pakistan J. Biological Science 2006;9(15):2916-2918.

Arakawa H, Choi S, Arimoto T, Nakamura Y. Relationship between underwater irradiance and distribution of Japanese common squid under fishing lights of a squid jigging boat. Fisheries Science 1998;64:553-557.

Arkhipkin AI. Squid as nutrient vectors linking Southwest Atlantic marine ecosystems. Deep. Res. Part II Top. Stud. Oceanogr. 2013;95:7–20. DOI: 10. 1016/j.dsr2.2012.07.003

Asokan K, Krishnan AR. Techniques to squid jigging in India: A review. J. Entomology and Zoology Studies, 2021;9(3):415-422. DOI: https://doi.org/10.22271/j.ento.2021.v9.i3f.8743

Aydin C, İlkyaz A. Catching performance and catching efficiency of siliconized baits in handline fishery. Journal of Agricultural Sciences (Tarim Bilimleri Dergisi) 2021;27(2): 219-230 DOI: 10.15832/ankutbd.606513

Brunetti NE. Description of *Rhynchoteuthion* larvae of *Illex argentinus* from summer spawning subpopulation. J. Plankton Res. 1990;12:1045-1057.

Cabanellas-Reboredo M, Alo´s J, Palmer M, Morales-Nin B. Environmental effects on recreational squid jigging fishery catches. ICES Journal of Marine Science 2012;69(10): 1823–1830. doi:10.1093/icesjms/fss159

Doubleday, Z. A., Prowse, T. A. A., Arkhipkin, A., Pierce, G. J., Semmens, J., Steer, M., et al. Global proliferation of cephalopods. Curr. Biol. 2016;26:387–407. DOI: 10.1016/j.cub.2016.04.002. FAO (2019).

Endler JA. A predator's view of animal color patterns. In Hecht MK, Steere WC, Wallace B, editors. Evolutionary Biology volume 11, 1978. p. 319-364.

FAO Yearbook: Fishery and Aquaculture Statistics 2017. Rome: Food and Agriculture Organization of the United Nations.

Flores EEdC, Igarashi S, Miiumi T. Studies on squid behavior in relation to fishing III. On the optomotor response of squid, *Todarodes pacificus* Steenstrup, to various colors. Bull. Fac. Fish. Hokkaido Univ. 1978;29(2):131-140.

Gilly WF, Markaida U, Baxter CH, Block BA, Boustany A, Zeidberg, et al. Vertical and horizontal migrations by the jumbo squid *Dosidicus gigas* were revealed by electronic tagging. Mar. Ecol. Prog. Ser. 2006;324:1–17. DOI: 10. 3354/meps324001

Hunsicker ME, Essington TE, Watson R, Sumaila UR. The contribution of cephalopods to global marine fisheries: can we have our squid and eat them too? Fish Fish. 2010;11:421–438. DOI: 10.1111/j.1467-2979.2010.00369. x

Hurst RJ, Ballara SL, MacGibbon D, Triantafillos L. Fishery characterization and standardized CPUE analyses for arrow squid (*Nototodarus gouldi* and *N. sloanii*), 1989–90 to 2007–08, and potential management approaches for southern fisheries. New Zealand Fisheries Assessment Report 2012;47. 303 p

Koopman M, Knuckey I, Cahill M. Improving the location and targeting of economically viable aggregations of squid available to the squid jigging method and the fleet's ability to catch squid. Australian Fisheries Management Authority. 2018;223 p.

Mallawa A, Palo SM, Musbir. Study on bagan Rambo fisheries in Barru waters, Makassar Strait. Research Report Project.Research Institute of Hasanuddin University. Makassar, (In Indonesian), 1991, 40p.

Mappes J, Marples N, Endler JA. The complex business of survival by aposematism. TRENDS in Ecology and Evolution, 2005; 20(11): 598-603.

Marchesan M, Spoto M, Verginella L, Ferrero EA. Behavioral effects of artificial light on fish species of commercial interest. Fish Res. 2005; 73:171-185.

Mochida K, Zang WY, Toda M. The function of body coloration of the hai coral snake *Sinomicrurus japonicus boettgeri*. Zoological Studies, 2015, 54:33. 6p.

Morales-Borjorquez E, Cisneros-Mata, MA, Nevarez-Martinez MO, Hernandez-Herrera A. Review of stock assessment and fishery biology of *Dosidicus gigas* in the Gulf of California, Mexico. Fisheries Research 2001;54: 83-94.

Nigmatullin CM, Nesis KN, Arkhipkin AI. A review of the biology of the jumbo squid *Dosidicus gigas* (Cephalopoda: Ommastrephidae). Fish. Res. 2001;54:9–19. DOI: 10.1016/S0165-7836(01)00371-X

Okutani T, Tung IH. Reviews of biology of commercially important squids in Japanese and adjacent waters, I. Symplectoteuthis oualaniensis (Lesson). Veliger. 1987;21(1): 87-94

Paighambari SY, Daliri M, Memarzade M. The effects of jig color and depth variation on catch rates of purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1830) in Iranian Waters of the Oman Sea. World Journal of Fish and Marine Sciences. 2012;4(5): 458-461. DOI: 10.5829/idosi.wjfms.2012.04.05.6415

Pierce GJ, Begoña Santos M, MacLeod CD, Wang J, Valavanis V, Zuur A. Modeling environmental influences on squid life history, distribution, and abundance. The role of squid in open ocean ecosystems, 16-17 November 2006, Hawaii, USA.

Pratasik SB, Lalamentik LTX, Manoppo L, Budiman J. Deep sea squid in Sulawesi Sea, North Sulawesi Province, Indonesia. Biodiversitas. 2022;23(4):1774-1779. DOI: 10.13057/biodiv/d230408

Rao KS. Cephalopod fishing. In Proceedings of the Seminar on Fisheries-A Multibillion Dollar Industry, Madras, Aug 17-19, 1995 Aquaculture Foundation of India & The Fisheries Technocrats Forum. 1996: 12-20.

Reza FA, Umroh, Utami E. The effect of bait types on squid Loligo sp capture in Tuing waters, Bangka Regency. J. Aquatropica Asia. 2019; 4 (1):20-25. [In Indonesian].

Roberts MJ, Sauer WHH. Environment: the key to understanding the South African chokka squid (*Loligo vulgaris reynaudio* life cycle and fishery? Antarctic Science. 1994; 6(2): 249-258.

Rodhouse PGK, Pierce GJ, Nichols OC, Sauer WHH, Arkhipkin AI, Laptikhovsky VV, et al. Environmental effects on cephalopod population dynamics. Adv. Mar. Biol. 2014;67, 99–233. DOI: 10.1016/b978-0-12- 800287-2.00002-0

Roper CEF, Sweeney MJ, Nauen C. Cephalopods of the World, Vol.3, An annotated and illustrated catalog of species of interest to fisheries. FAO Fisheries Synopsis 1984; 125, Rome, 277pp.

Solomon OO, Ahmed OO. Fishing with light: Ecological consequences for coastal habitats. International Journal of Fisheries and Aquatic Studies 2016; 4(2): 474-483

Stewart JS, Gilly WF, Field JC, Payne JC. Onshore-offshore movement of jumbo squid (*Dosidicus gigas*) on the continental shelf. Deep. Res. II Top. Stud. Oceanogr. 2013;95: 193–196. DOI: 10.1016/j.dsr2.2012. 08.019

Toledo LF, Haddad CFB. Colors and some morphological traits as defensive mechanisms in Anurans. Int. J. Zoology, 2009; 12p.

Tung IH. On the fishery and biology of the squid, *Ommastrephes bartramii*, in the northwest Pacific Ocean. Rep.Inst.Fish.Biol., Taipei, 1981;3(4): 12-37.

Ulaş A, Aydin I. The effect of jig colors and lunar brightness on coastal squid jigging. African Journal of Biotechnology. 2011; 10(9):1721-1726. DOI: 10.5897/AJB10.1775

Voss, G. L., 1973. Cephalopod resources of the world. FAO Fish. Circ. 1973; 149: 75p.

Worms, J. World fisheries for cephalopods: A synoptic overview. In J. F. Caddy. 1983 (Ed.) Advances in Assessment of World Cephalopod Resources. FAO Tech. FAO. Rome. 1083; 231:1-20.

Yamashita Y, Matsushita Y, Azuno T. Catch performance of coastal squid jigging boats using LED panels in combination with metal halide lamps. Fisheries Research 2012;113:182-189

Yoshikawa N. Fisheries in Japan: Squid and Cuttlefish. Tokyo, Japan Marine Products Photo Materials Association. 1978; 161p.

Yu W, Chen X, Yi Q, Chen Y, Zhang Y. Variability of Suitable Habitat of Western Winter-Spring Cohort for Neon Flying Squid in the Northwest Pacific under Anomalous Environments. PLoS ONE 2015;10(4): e0122997. doi:10.1371/journal. pone.0122997

Table 1. ANOVA on the effect of artificial bait light colors on the number of catches.

Source of Variance	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Main Effects					
A: Trip	85653.0	9	9517.0	24.96	0.0000
B: Bait light color	$1.22351*10^{-6}$	3	407836.	1069.59	0.0000
A-B interactions	16791.1	27	621.892	1.63	0.0488
RESIDUAL	30504.0	80	381.3		
TOTAL	$1.35646*10^{-6}$	119			

Table 2. Multiple comparisons between treatment applications.

Bait light color comparisons	Difference	+/- Limits
BLUE – COM	171.167*	13.229
BLUE – GREEN	-109.067*	13.229
BLUE – RED-GREEN	54.8667*	13.229
COM – GREEN	-280.233*	13.229
COM – RED-GREEN	-116.3*	13.229
GREEN – RED-GREEN	163.933*	13.229

Note: * - significant difference

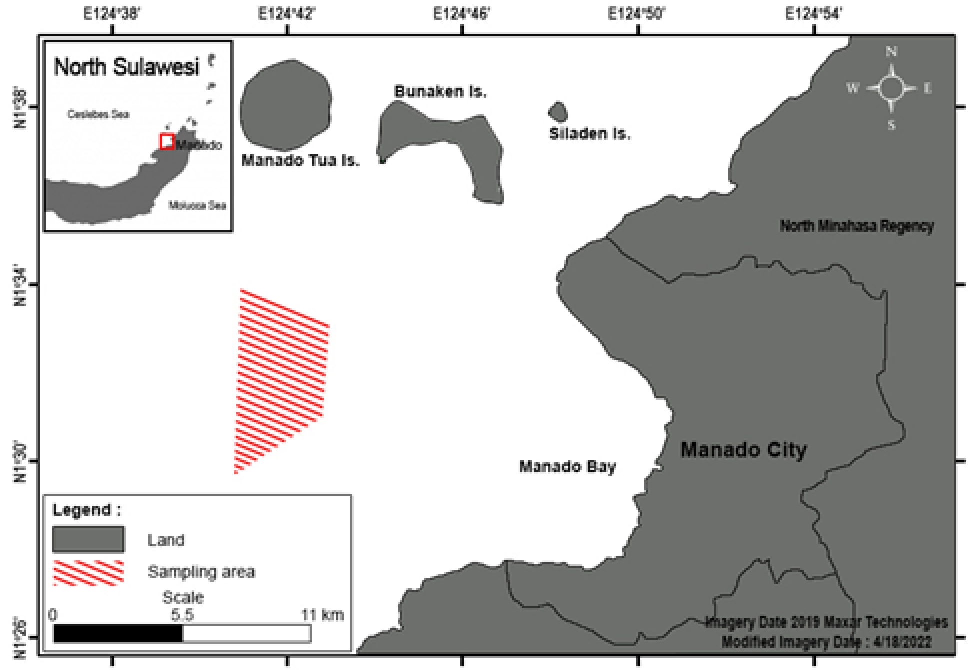


Figure 1. Sampling site

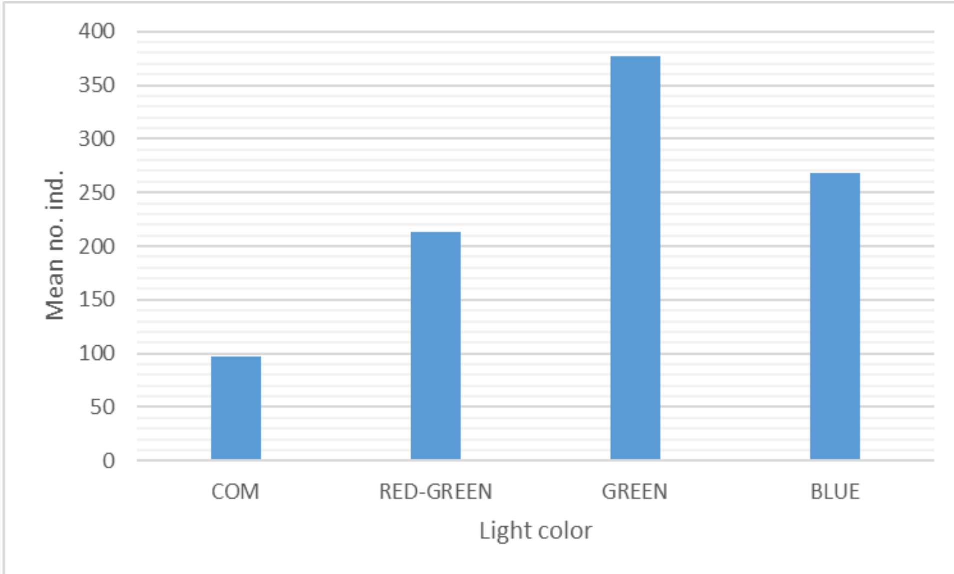


Figure 2. Mean catch of squid *S. oualaniensis* during the study.

Copyright Transfer Agreement, Disclosure of Conflict of Interest and Statement of Ethics

- Fisheries and Aquatic Sciences -

Please complete this form and upload their scanned copies on submission site

Manuscript title: Behavioral Response of purpleback flying squid *Sthenoteuthis oualaniensis* (Mollusk; Cephalopod) to the flashlight artificial bait color

---

Originality, authorship and publication ethics

1. I confirm that this manuscript is original and is not currently under consideration for publication by any other scientific journal.
2. I confirm that no part of this manuscript is duplicated or violates the copyright of others.
3. I attest that I have made an important scientific contribution to the study and have assisted with the drafting or revising of the manuscript in accordance with the definition of an author.
4. I fully agree with the data and the conclusions presented in the final manuscript.
5. I declare that I conform to the publication and research ethics.

Copyright assignment agreement

I hereby assign all rights, including but not limited to the copyright, for this manuscript to the journal upon its acceptance for publication, and that the journal has the right to publish, republish, transmit, sell and distribute them in the journal or other media.

Potential conflict of interest disclosure

We declare that potential conflicts of interest for all Authors, or acknowledgment that no conflicts exist, are included in the manuscript. Disclosures include financial support for this study, consultation fee and stocks and relationships with a company whose products or services are related to the subject matter of the manuscript. All authors agreed to the terms outlined in this document and approved the submission of this manuscript for publication.

Name of the author	Date	Signature
Silvester Benny Pratasik	Agustus 10th, 2022	
Lefrand Manoppo	Agustus 10th, 2022	
Effendi Pangihutan Sitanggang	Agustus 10th, 2022	
Lusia Manu	Agustus 10th, 2022	

*All author(s) should sign this form in the order listed in the manuscript.

Copyright Transfer Agreement, Disclosure of Conflict of Interest and Statement of Ethics

- Fisheries and Aquatic Sciences -

Please complete this form and upload their scanned copies on submission site

Manuscript title: Behavioral Response of purpleback flying squid *Sthenoteuthis oualaniensis* (Mollusk; Cephalopod) to the flashlight artificial bait color

---

Originality, authorship and publication ethics

1. I confirm that this manuscript is original and is not currently under consideration for publication by any other scientific journal.
2. I confirm that no part of this manuscript is duplicated or violates the copyright of others.
3. I attest that I have made an important scientific contribution to the study and have assisted with the drafting or revising of the manuscript in accordance with the definition of an author.
4. I fully agree with the data and the conclusions presented in the final manuscript.
5. I declare that I conform to the publication and research ethics.

Copyright assignment agreement

I hereby assign all rights, including but not limited to the copyright, for this manuscript to the journal upon its acceptance for publication, and that the journal has the right to publish, republish, transmit, sell and distribute them in the journal or other media.

Potential conflict of interest disclosure

We declare that potential conflicts of interest for all Authors, or acknowledgment that no conflicts exist, are included in the manuscript. Disclosures include financial support for this study, consultation fee and stocks and relationships with a company whose products or services are related to the subject matter of the manuscript. All authors agreed to the terms outlined in this document and approved the submission of this manuscript for publication.

Name of the author	Date	Signature
Silvester Benny Pratasik	Agustus 10th, 2022	
Lefrand Manoppo	Agustus 10th, 2022	
Effendie Sitanggang	Agustus 10th, 2022	
Lusia Manu	Agustus 10th, 2022	

*All author(s) should sign this form in the order listed in the manuscript.

Fisheries and Aquatic Sciences
Indexed in SCOPUS and KCI
eISSN : 2234-1757

Journal Title: Fisheries and Aquatic Sciences

Manuscript ID: fas-2022-0089

Degree (Date created): 2nd (2022-11-28)

Manuscript Title: Behavioral Response of Purpleback Flying Squid Sthenoteuthis oualaniensis (Mollusk; Cephalopod) to the Flashlight Artificial Bait Colors

Running Title: Effect of bait color on squid's feeding rate

Urgency: Normal Manuscript

Type: Research Article

Category: Ecology and Fisheries Resource Management;

Respond to review: Response to Reviews

We would firstly thank all comments on this paper. We have checked and added some additional information to give a better understanding of how the experiment was done.

Reviewer 1: The paper has been revised by adding some information in either method or result part. We put all revisions in Red.

Reviewer 2: The purpose of this paper is to find out the most effective artificial baits for baits with different colors in squid jigging fishery.

We have realized that this study was so simple experimental study and focuses only on the effect of the light color or the artificial bait. Therefore, the use of 10 fishing trips is considered enough to explain the response of the squid to the flashlight, since we used the catch data as a response parameter. We did not include the environmental factors that might influence the squid catches, because we assume that the squid population is evenly affected by environmental factors. In this case, we have put some additional information to explain the results.

Reviewer 3: We put the artificial bait picture in Figure 2 with additional information on how the squids were caught (RED).

Fisheries and Aquatic Sciences
Address: Pukyong National University, 45 Yongso-ro, Nam-gu, Busan 48513, Korea
Tel: +82-51-629-7363,
Email: kosfas@kosfas.or.kr
Homepage: http://www.e-fas.org/

Behavioral Response of Purpleback Flying Squid *Sthenoteuthis oualaniensis* (Mollusk; Cephalopod) to the Flashlight Artificial Bait Colors

Silvester B. Pratasik[1)], Lefrand Manoppo[2)], Effendi P. Sitanggang[2)], Lusia Manu[2)]

[1)]Fisheries Resources Management, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Jl. Kampus Bahu Manado-95115, North Sulawesi, Indonesia; [2)]Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Jl. Kampus Bahu Manado-95115, North Sulawesi, Indonesia. Corresponding author: S.B. Pratasik, spjong07@yahoo.com

ABSTRACT. This study aimed to know the response of deep-sea squid *Sthenoteuthis oualaniensis* to the light colors of the artificial bait. This experiment used the commercial artificial flashlight baits commonly sold in the fishing shop. The bait has several different light color combinations. The light colors were modified into several light colors by inactivating certain colors and used as treatments. We applied red-green, green, blue, and commercial bait lights in this study. Each treatment has 3 replications. The effect was expressed as the amount of squid caught. Data were analyzed by One-Way ANOVA. Results showed a significant effect on the number of squid catches. There was significantly different squid catches among the treatments. It indicates that this artificial flashlight bait could be developed to maximize squid catches.

Keywords: commercial jig, modification, effect, catch.

Introduction

The exploitation of fisheries resources starts from a basic human need to obtain animal protein sources. Squid is one of the protein sources from the ocean, and nearly all body parts are edible. Since 1950, capture production of cephalopods has continued to grow (Hunsicker et al., 2010; Doubleday et al., 2016), with total commercial annual catches between 3.5 and 4.9 million tons in 2008–2017 (FAO, 2019), almost 4.6 times higher than that of the 1950s. Cephalopods on average support approximately 15 and 20% of marine fishery landings and landed values, respectively (Hunsicker et al., 2010; FAO, 2019). This group has unique life history characteristics, including rapid growth, short lifespan, and semelparous reproductive strategy, giving them both sensitivity and resilience to anthropogenic exploitation and oceanographic variability (Rodhouse et al., 2014). The species within the family Ommastrephidae support approximately 33.8% of the global cephalopod's landings (FAO, 2019). This group is recognized as voracious and adaptable predators of a broad range of prey including small crustaceans and fishes at early life stages and shift to micronekton, larger fishes, and cephalopods (including cannibalism) as they grow (Nigmatullin et al., 2001; Alegre et al., 2014). Despite its economic importance, the offshore oceanic squid resources' exploitation rate is relatively low (Worms, 1983). The flying squids (Ommastrephidae; Oegopsid) cover about 65% of the world's commercial cephalopods (Roper et al. 1984; Brunetti 1990) with a total of about 2.6 million in 1991 (FAO 1993). The flying squids *Sthenoteuthis oualaniensis* (Lesson) and *Ommastrephes* *bratamii* are the oceanic species of this family that are distributed from the Indo-Pacific to the Indian Ocean. According to Voss (1973), the potential of the purpleback flying squids in the Central Eastern Pacific is at least 100,000 metric tons. This species is caught commercially in the eastern and southern East China Sea, from Taiwan to Okinawa by hook and line with light at night (Yoshikawa 1978; Okutani 1980; Tung 1981,). The deep-sea squids caught by traditional fishermen of Manado Bay, North Sulawesi, in the Sulawesi Sea have been identified as a dwarf form of *Sthenoteuthis oualaniensis* (Pratasik et al., 2022). These species are highly migratory and undertake diel vertical migrations of several hundred meters and seasonal migrations between the shelf and open ocean (Gilly et al., 2006; Stewart et al., 2013) so that they can act as important linkages between both neritic and oceanic food webs (Arkhipkin, 2013).

There are numerous studies on bait types to find the highest catch, from fish and shrimp flesh, live bait, and artificial bait. Fish and **s**quids were observed to be attracted to squid jigging vessels due to the phototaxis (Rao. 1996). It is related to their behavior to avoid predators or enhance feeding efficiency (Solomon and Ahmed, 2016), and their response depends upon species, ontogenic development, light source characteristics, intensity, color, and wavelength (Mallawa et al., 1991). Therefore, fishermen catch squid using light that illuminates in water as well as jigs to attract the squids to aggregate and bite the jigs (Asokan and Krishnan, 2021). It relies on the artificial bait of shrimp-like siliconized jig fishing (Altinagac, 2006; Ulas & Aydin, 2011; Paighambari et al., 2012; Reza et al., 2019**;** Aydin & Ilkyaz, 2021**).** Other studies on hand-line fishing are also done using different colors of shrimp-shaped jigs (Altinagac, 2006; Ulas & Aydin, 2011; Paighambari et al., 2012; Aydin & Ilkyaz, 2021). Squid fishing in North Sulawesi is done by traditional fishermen using 5 to 7 M-boat and artificial bait either shrimp-like bait or other bait types (Figure 1).

Figure 1. Artificial bait. (a) shrimp-like bait and (b) flashlight jig: 1) flashlight; 2) one-meter line; 3) lead; 4) hook.

For deep-sea squid *S. oualaniensis* fishing, the fishermen use a mini-battery-supported flashlight artificial bait sold in the fishing stores. The flashlight artificial bait contains several different alternately blinking light colors to get the squid to bite. This study modifies the light colors to find the best modification of light color against the catches.

Method

This study was carried out from June to July 2020. Traditional fishermen catch deep-sea *squids S. oualaniensis* in the Sulawesi Sea, North Sulawesi, at night (Figure 2). The flashlight bait is facilitated with a mini-battery to be able to produce several different light colors to attract the squid. The flashlight was connected by a one-meter line to the hook working also as a lead. In fishing operations, the lead was coated with fish flesh as bait.

This experiment modified the standard commercial flashlight bait sold in the fishing shop to produce different light colors: Red-Green, Blue, Green, and Red. These different light colors were used in 10 fishing trips. Twelve skillful fishermen were used in this experiment in which they were divided into 4 groups of 3 people in 4 separate traditional boats (7 m long) to operate each light color in the same fishing ground. The common commercial flashlight bait was also used as a control treatment. Each line used only one jig and all jig-fishing activities were carried out at the same time. The fishing line was lowered down to the depth range of 20-25 M in the deep sea of Sulawesi Sea waters and jigged. This fishing depth is consistent with the dispersal range peak of *S. oualaniensis* (Jerep and Ropper, 2010).

Figure 2. Sampling site.

The use of the red-colored bait was eventually terminated because it was always cut off and lost. The experiment utilized only commercial bait, red-green bait, blue bait, and green bait as treatment with 3 replications represented by 3 local skillful fishermen for each bait light color. Data collections were squid catches. The catch data were analyzed with one-way ANOVA facilitated by statistical software for comparisons. The difference between treatments was then tested using Tukey's Honestly Significant Difference (HSD) procedure.

Results

This study caught a total of 30,687 squids *S. oualaniensis* during the fishing experiment in the Sulawesi Sea, North Sulawesi. Different light color applications highly significantly influenced the number of squid catches ($P<0.001$). Analysis of Variance demonstrates that both trip and bait light color influence the squid catches (Table 1).

Table 1. ANOVA on the effect of artificial bait light colors on the number of catches.

Tukey's Honestly Significant Difference (HSD) test revealed that *S. oualaniensis* differently responded to the bait's light colors. All treatment applications gave a significantly different number of catches. Comparisons between treatments showed that all bait light color modifications gave a higher number of catches than the commercial one (Table 2).

Table 2. Multiple comparisons between treatment applications.

The significantly different squid catches are also indicated by the mean number of squid catches (Figure 3). The green-lighted jig yielded the highest mean squid catches, 377.37 (39.46%), followed by blue light color, 268.3 (28.06%), then red-green, 213.43 (22.32%), and the lowest catches in the commercial artificial bait, 97.13 (10.16%) (Table 2 and Figure 3). Multiple comparisons between treatment applications yielded 6 pairs of comparisons and indicated that all treatment flashlight jig colors yielded significantly different squid catches, in which single light colors also give the squid a higher response to taking the lure (Table 2).

Figure 3. Mean catch of squid *S. oualaniensis* during the study.

Discussion

Jigging is an essential fishing method to exploit squids selectively and avoid overexploiting to conserve resources and energy (Asokan & Krishnan, 2021). It helps to adjust operational depth according to the concentration depth of squids. They are attracted to lights and fast-moving bait or any bait-like object. A typical jig consists of a shrimp or stalk-like body made of flexible plastic with one to three hooks or more sharp barbless steel hooks at the end. Other jigs are facilitated with the mini battery-supported light blinking.

Squids are known as color-blinded animals, but the degree of contrast is important for squid behavior to attack the jig (Flores et al., 1978). The use of a flashlight jig, in fact, gave a stronger degree of contrast in the water column at night fishing than the use of light above the water and could give a stronger stimulus to the squid to attack the fish flesh bait connected to blinking light. The flashlight jig also has a higher degree of contrast than the shrimp-like siliconized jig so that the squid more sensitively responds to the flashlight jig color in the water column. The flashlight acts as a squid-aggregating device, while the squid feeds on the fish's flesh, then caught by the hook. The flashlight jig could help the purpleback flying squid get the bait. All squids were hooked on the arms, indicating that the squids are feeding on the fish's flesh coated on the lead. On the other hand, cephalopods (squid, cuttlefish, and octopus) are well known as voracious predators of many preys, such as fish and crustaceans, or even have cannibalism behavior, so the contrast moving objects in the water column could indicate the presence of moving prey.

Furthermore, the present study revealed that the modified light colors of the artificial bait caught a higher number of deep-sea squid *S. oualaniensis* in the Sulawesi Sea than the common commercial artificial bait sold in the fishing store with a combination of several different colors. There was also a significantly different effect of all light color modifications on the squid catches with the highest catch in the green light. The low attacking preference of the purpleback flying squid to the multiple light colors could result from the squid's perception of the blinking multiple colors of the flashlight bait as the aposematic coloration of the prey, in which the animal shows the unpalatability or toxicity through warning coloration. This defense mechanism is widely discussed by Endler (1978), Mappes et al (2005), Mochida et al (2015), Stevens (2007), and Toledo & Haddad (2009). Aposematism is commonly found across the animal kingdom as a defense mechanism, and it could either be chemicals, such as toxins, harmful secretions, and venoms, or physical defense, such as spines, bites, and stings (Mappes *et al.*, 2005).

This finding is in agreement with Altinagac (2006) and Paighambari et al (2012) that the green bait color is more efficient in squid jig fishing even though it does not have a significantly different effect from the use of red color in Turkish waters (Altinagac 2006) and the blue color (Paighambari et al., 2012) on the catch rate of purpleback flying squids in Iranian waters of the Oman Sea. The sensitivity of fish and some of their food animals to blue and green colors is higher because of the long wavelengths that make them penetrate deeper into the water column

(Solomon & Ahmed 2016). The use of dark green jig color is also shown by the traditional fishermen, particularly in North Minahasa, North Sulawesi, as a potential bait color for demersal fish jig fishing (field obs.). Nevertheless, Ulaş and Aydin (2012) found that the red jig is the most efficient in squid *Loligo vulgaris* Lamarck (1798) fishing on the Middle Eastern Coast of Aegean Sea, Turkey. All those findings were obtained using the shrimp-like siliconized bait. The local fishermen of North Sulawesi commonly use the shrimp-like siliconized jig to fish shallow water squids *Sepioteuthis lessoniana.* A different finding is shown by Arnupapboon et al (2008) that the squid moves to white and blue more often than green, while the red color seemed not to attract the squids.

This fishing experiment reconfirms the previous finding concerning the most efficient bait color and shows that the use of single bait light color yielded higher catches than that of multiple colors ($P<0.05$). This study did not use the red light color as a treatment, since the red-lighted bait was always taken and cut off. Therefore, we had to use a wireline to the bait to know what causes the loss and found that the red light color was taken by the cutlassfish *Trichiurus* sp. The difference in squid's preference for jig color could result from environmental conditions with locality, such as predator-prey interactions that may alter the feeding behavior on-site and species. The presence of a higher level of the predator, such as cutlassfish *Trichiurus* sp, particularly in Sulawesi waters which is also attracted to the red-light jig has diminished the chance of the deep-sea squids *S. oualaniensis* to take the red jig or the squid *S. oualaniensis* is vulnerable to predation risk for feeding on the red-light jig.

According to Asokan and Krishnan (2021), the efficiency of squid jigging is influenced by jig structure, jigging motion, light intensity, sea state, and sea surface temperature (Cabanellas-Reboredo et al., 2012; Roberts and Sauer, 1994; Yu et al., 2015), wind speed, moon phase, and atmospheric pressure (Cabanellas-Reboredo et al., 2012), sea surface height anomaly (Yu et al., 2015), turbidity (Roberts and Sauer, 1994), chlorophyll (Hurst et al., 2012), salinity (Yu et al., 2015), and large scales climate predictors, such as the Southern Oscillation Index (SOI) and the North Atlantic Oscillation (NAO) (Roberts and Sauer, 1994; Morales-Bojorquez et al. 2001; Pierce et al., 2006). etc. These factors will influence the catches, recruitment, migration (Koopman et al (2018), and distribution of the squids. During squid jigging with lights, the quality of light (e.g. wavelength), the quantity of light (e.g. power), and the arrangement of fishing lights affect the squid's attraction. These factors create underwater irradiance levels and distribution influenced by the optical characteristics of seawater, and it influences squid behavior during fishing (Arakawa et al., 1998; Yamashita et al., 2012). According to Cabanellas-Reboredo et al. (2012), environmental variables, such as sea surface temperature, atmospheric pressure, and moon cycle can also influence squid catches. This experiment focused only on the effect of different jig light colors on the squid bites since the fishing was conducted in a single lunar cycle with different tide conditions. The jiggers took advantage of wind or current direction to position their boats in certain areas to avoid being drifted too far out of the mainland due to the use of the small boat (approximately 5-7 M long).

These findings showed that all light color modifications of the multiple flashlight-squid baits have contributed to the artificial squid flashlight bait development concerning the squid fishing effectivity. Light colors also influenced the feeding behavior of *S. oualaniensis*, and the single color gave a higher response of the squid to getting the lure than the multiple colors. The highest squid catch was recorded in the green light color and the lowest was in the commercial artificial bait. Therefore, the present study has contributed to the development of mini-battery-supported artificial bait for effective exploitation to maximize squid production and squid fisheries development offshore. This information is also useful for traditional fishermen to increase their personal income through deep-sea squid fishing. Nevertheless, more studies on squid feeding behavior and other influencing environmental factors are needed for future squid population sustainability.

Competing Interests

This article has no competing interests.

Acknowledgments

We would greatly appreciate the Rector of Sam Ratulangi University and the Dean of the Faculty of Fisheries and Marine Sciences who provided a small research grant. High appreciation is also addressed to Mr. Ponny Telleng who led the local fishermen of Manado Bay in fishing operations.

References

Altinagac U. Effect of jigs color on catching efficiency in squid fishing in Turkey. Pakistan J. Biological Science 2006;9(15):2916-2918.

Arakawa H, Choi S, Arimoto T, Nakamura Y. Relationship between underwater irradiance and distribution of Japanese common squid under fishing lights of a squid jigging boat. Fisheries Science 1998;64:553-557.

Arkhipkin AI. Squid as nutrient vectors linking Southwest Atlantic marine ecosystems. Deep. Res. Part II Top. Stud. Oceanogr. 2013;95:7–20. DOI: 10. 1016/j.dsr2.2012.07.003.

Arnupapboon S, Awaiwanont K, Anongponyoskun M, Annanpongsuk S, Chokesanguan B. Boosting the development of responsible squid light fishery. Assessment of squid feeding behavior Southeast Asian Fisheries Development Center. Fish for the people 2008; 6(1):44-47 2008

Asokan K, Krishnan AR. Techniques to squid jigging in India: A review. J. Entomology and Zoology Studies, 2021;9(3):415-422. DOI: https://doi.org/10.22271/j.ento.2021.v9.i3f.8743

Aydin C, İlkyaz A. Catching performance and catching efficiency of siliconized baits in handline fishery. Journal of Agricultural Sciences (Tarim Bilimleri Dergisi) 2021;27(2): 219-230 DOI: 10.15832/ankutbd.606513

Brunetti NE. Description of *Rhynchoteuthion* larvae of *Illex argentinus* from summer spawning subpopulation. J. Plankton Res. 1990;12:1045-1057.

Cabanellas-Reboredo M, Alo´s J, Palmer M, Morales-Nin B. Environmental effects on recreational squid jigging fishery catches. ICES Journal of Marine Science 2012;69(10): 1823–1830. doi:10.1093/icesjms/fss159

Doubleday, ZA., Prowse TAA, Arkhipkin, A, Pierce GJ, Semmens J, Steer M., et al. Global proliferation of cephalopods. Curr. Biol. 2016;26:387–407. DOI: 10.1016/j.cub.2016.04.002. FAO (2019).

Endler JA. A predator's view of animal color patterns. In Hecht MK, Steere WC, Wallace B, editors. Evolutionary Biology volume 11, 1978. p. 319-364.

FAO Yearbook: Fishery and Aquaculture Statistics 2017. Rome: Food and Agriculture Organization of the United Nations.

Flores EEdC, Igarashi S, Miiumi T. Studies on squid behavior in relation to fishing III. On the optomotor response of squid, *Todarodes pacificus* Steenstrup, to various colors. Bull. Fac. Fish. Hokkaido Univ. 1978;29(2):131-140.

Gilly WF, Markaida U, Baxter CH, Block BA, Boustany A, Zeidberg, et al. Vertical and horizontal migrations by the jumbo squid *Dosidicus gigas* were revealed by electronic tagging. Mar. Ecol. Prog. Ser. 2006;324:1–17. DOI: 10. 3354/meps324001

Hunsicker ME, Essington TE, Watson R, Sumaila UR. The contribution of cephalopods to global marine fisheries: can we have our squid and eat them too? Fish Fish. 2010;11:421–438. DOI: 10.1111/j.1467-2979.2010.00369. x

Hurst RJ, Ballara SL, MacGibbon D, Triantafillos L. Fishery characterization and standardized CPUE analyses for arrow squid (*Nototodarus gouldi* and *N. sloanii*), 1989–90 to 2007–08, and potential management approaches for southern fisheries. New Zealand Fisheries Assessment Report 2012;47. 303 p

Jerep P, Roper CF. Cephalopods of the World. An Annotated and Illustrated Catalogue of Cephalopod Species Known to date, 2010; Vol. 2. Myopsid and Oegopsid. FAO, Rome.

Koopman M, Knuckey I, Cahill M. Improving the location and targeting of economically viable aggregations of squid available to the squid jigging method and the fleet's ability to catch squid. Australian Fisheries Management Authority. 2018;223 p.

Mallawa A, Palo SM, Musbir. Study on bagan Rambo fisheries in Barru waters, Makassar Strait. Research Report Project.Research Institute of Hasanuddin University. Makassar, (In Indonesian), 1991, 40p.

Mappes J, Marples N, Endler JA. The complex business of survival by aposematism. TRENDS in Ecology and Evolution, 2005; 20(11): 598-603.

Marchesan M, Spoto M, Verginella L, Ferrero EA. Behavioral effects of artificial light on fish species of commercial interest. Fish Res. 2005; 73:171-185.

Mochida K, Zang WY, Toda M. The function of body coloration of the hai coral snake *Sinomicrurus japonicus boettgeri.* Zoological Studies, 2015, 54:33. 6p.

Morales-Borjorquez E, Cisneros-Mata, MA, Nevarez-Martinez MO, Hernandez-Herrera A. Review of stock assessment and fishery biology of *Dosidicus gigas* in the Gulf of California, Mexico. Fisheries Research 2001;54: 83-94.

Nigmatullin CM, Nesis KN, Arkhipkin AI. A review of the biology of the jumbo squid *Dosidicus gigas* (Cephalopoda: Ommastrephidae). Fish. Res. 2001;54:9–19. DOI: 10.1016/S0165-7836(01)00371-X

Okutani T, Tung IH. Reviews of biology of commercially important squids in Japanese and adjacent waters, I. Symplectoteuthis oualaniensis (Lesson). Veliger. 1987;21(1): 87-94

Paighambari SY, Daliri M, Memarzade M. The effects of jig color and depth variation on catch rates of purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1830) in Iranian Waters of the Oman Sea. World Journal of Fish and Marine Sciences. 2012;4(5): 458-461. DOI: 10.5829/idosi.wjfms.2012.04.05.6415

Pierce GJ, Begoña Santos M, MacLeod CD, Wang J, Valavanis V, Zuur A. Modeling environmental influences on squid life history, distribution, and abundance. The role of squid in open ocean ecosystems, 16-17 November 2006, Hawaii, USA.

Pratasik SB, Lalamentik LTX, Manoppo L, Budiman J. Deep sea squid in Sulawesi Sea, North Sulawesi Province, Indonesia. Biodiversitas. 2022;23(4):1774-1779. DOI: 10.13057/biodiv/d230408

Rao KS. Cephalopod fishing. In Proceedings of the Seminar on Fisheries-A Multibillion Dollar Industry, Madras, Aug 17-19, 1995 Aquaculture Foundation of India & The Fisheries Technocrats Forum. 1996: 12-20.

Reza FA, Umroh, Utami E. The effect of bait types on squid Loligo sp capture in Tuing waters, Bangka Regency. J. Aquatropica Asia. 2019; 4 (1):20-25. [In Indonesian].

Roberts MJ, Sauer WHH. Environment: the key to understanding the South African chokka squid (*Loligo vulgaris reynaudio* life cycle and fishery? Antarctic Science. 1994; 6(2): 249-258.

Rodhouse PGK, Pierce GJ, Nichols OC, Sauer WHH, Arkhipkin AI, Laptikhovsky VV, et al. Environmental effects on cephalopod population dynamics. Adv. Mar. Biol. 2014;67, 99–233. DOI: 10.1016/b978-0-12- 800287-2.00002-0

Roper CEF, Sweeney MJ, Nauen C. Cephalopods of the World, Vol.3, An annotated and illustrated catalog of species of interest to fisheries. FAO Fisheries Synopsis 1984; 125, Rome, 277pp.

Solomon OO, Ahmed OO. Fishing with light: Ecological consequences for coastal habitats. International Journal of Fisheries and Aquatic Studies 2016; 4(2): 474-483

Stewart JS, Gilly WF, Field JC, Payne JC. Onshore-offshore movement of jumbo squid (*Dosidicus gigas*) on the continental shelf. Deep. Res. II Top. Stud. Oceanogr. 2013;95: 193–196. DOI: 10.1016/j.dsr2.2012. 08.019

Toledo LF, Haddad CFB. Colors and some morphological traits as defensive mechanisms in Anurans. Int. J. Zoology, 2009; 12p.

Tung IH. On the fishery and biology of the squid, *Ommastrephes bartramii*, in the northwest Pacific Ocean. Rep.Inst.Fish.Biol., Taipei, 1981;3(4): 12-37.

Ulaş A, Aydin I. The effect of jig colors and lunar brightness on coastal squid jigging. African Journal of Biotechnology. 2011; 10(9):1721-1726. DOI: 10.5897/AJB10.1775

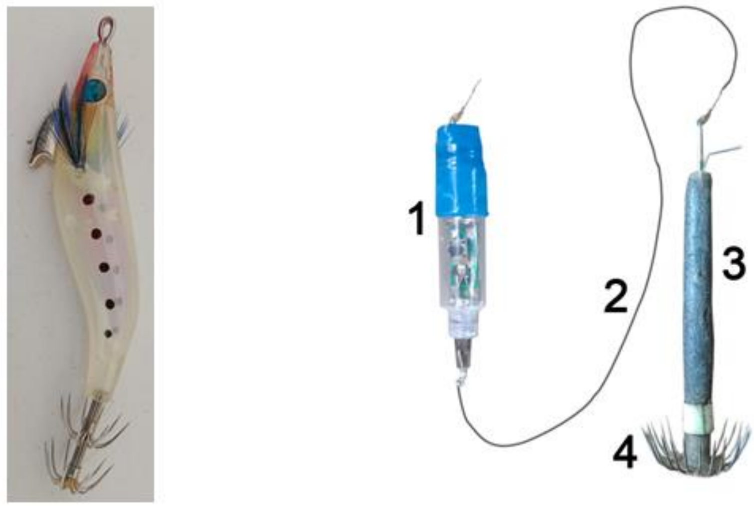
Voss, G. L., 1973. Cephalopod resources of the world. FAO Fish. Circ. 1973; 149: 75p.

Worms, J. World fisheries for cephalopods: A synoptic overview. In J. F. Caddy. 1983 (Ed.) Advances in Assessment of World Cephalopod Resources. FAO Tech. FAO. Rome. 1083; 231:1-20.

Yamashita Y, Matsushita Y, Azuno T. Catch performance of coastal squid jigging boats using LED panels in combination with metal halide lamps. Fisheries Research 2012;113:182-189

Yoshikawa N. Fisheries in Japan: Squid and Cuttlefish. Tokyo, Japan Marine Products Photo Materials Association. 1978; 161p.

Yu W, Chen X, Yi Q, Chen Y, Zhang Y. Variability of suitable habitat of western winter-spring cohort for neon flying squid in the Northwest Pacific under anomalous environments. PLoS ONE 2015;10(4): e0122997. doi:10.1371/journal. pone.0122997



(a) (b)

Figure 1. Artificial bait. (a) shrimp-like bait and (b) flashlight jig.

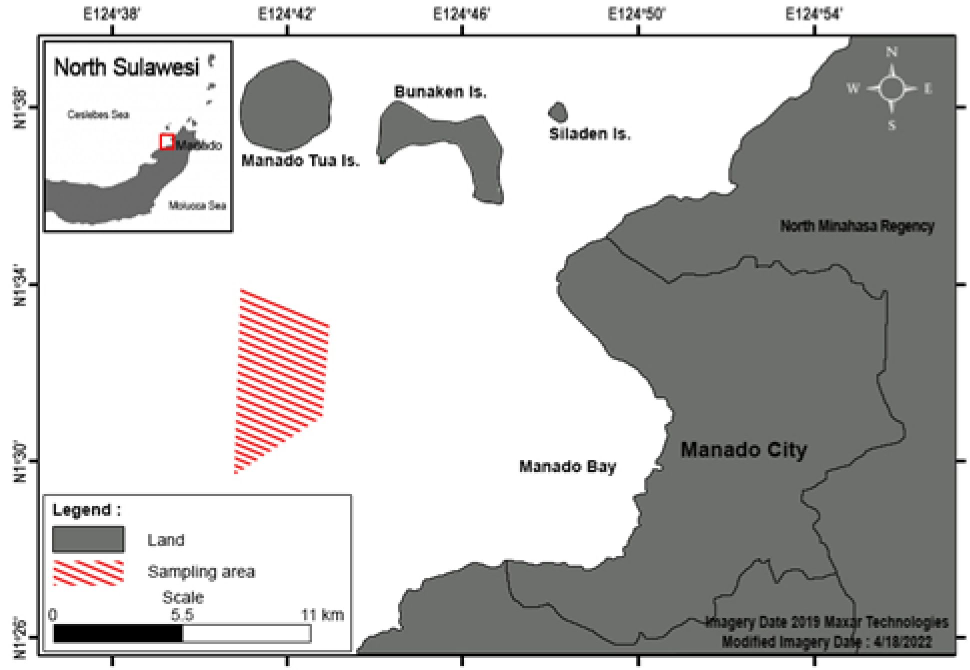


Figure 2. Sampling site

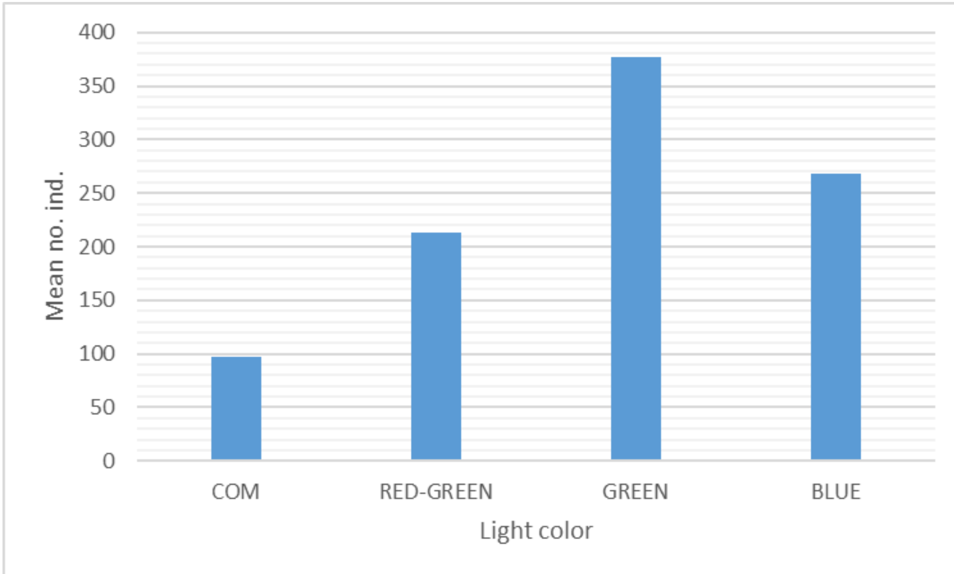


Figure 3. Mean catch of squid *S. oualaniensis* during the study.

Table 1. ANOVA on the effect of artificial bait light colors on the number of catches.

Source of Variance	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Main Effects					
A: Trip	85653.0	9	9517.0	24.96	0.0000
B: Bait light color	$1.22351*10^{-6}$	3	407836.	1069.59	0.0000
A-B interactions	16791.1	27	621.892	1.63	0.0488
RESIDUAL	30504.0	80	381.3		
TOTAL	$1.35646*10^{-6}$	119			

Table 2. Multiple comparisons between treatment applications.

Bait light color comparisons	Difference	+/- Limits
BLUE – COM	171.167*	13.229
BLUE – GREEN	-109.067*	13.229
BLUE – RED-GREEN	54.8667*	13.229
COM – GREEN	-280.233*	13.229
COM – RED-GREEN	-116.3*	13.229
GREEN – RED-GREEN	163.933*	13.229

Note: * - significant difference

Response to Reviews

We would firstly thank all comments on this paper. We have checked and added some additional information to give a better understanding of how the experiment was done.

Reviewer 1: The paper has been revised by adding some information in either method or result part. We put all revisions in Red.

Reviewer 2: The purpose of this paper is to find out the most effective artificial baits for baits with different colors in squid jigging fishery.

We have realized that this study was so simple experimental study and focuses only on the effect of the light color or the artificial bait. Therefore, the use of 10 fishing trips is considered enough to explain the response of the squid to the flashlight, since we used the catch data as a response parameter. We did not include the environmental factors that might influence the squid catches, because we assume that the squid population is evenly affected by environmental factors. In this case, we have put some additional information to explain the results.

Reviewer 3: We put the artificial bait picture in Figure 2 with additional information on how the squids were caught (RED).

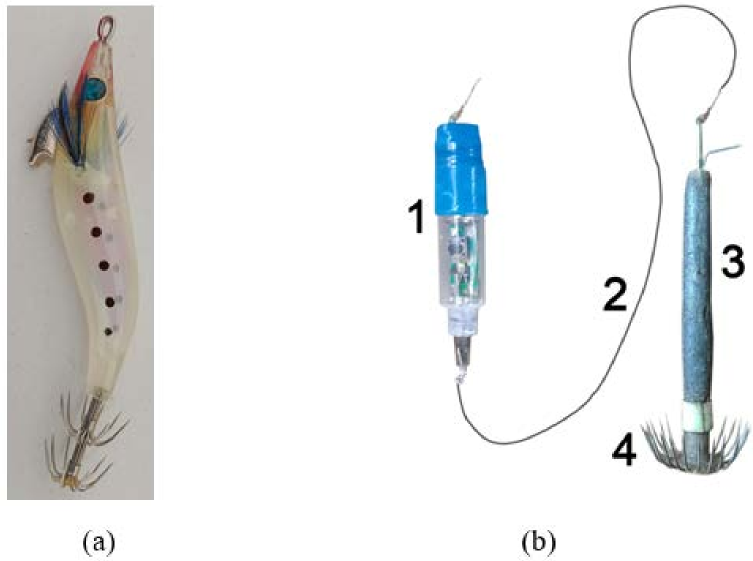


Figure 1. Artificial bait. (a) shrimp-like bait and (b) flashlight jig.

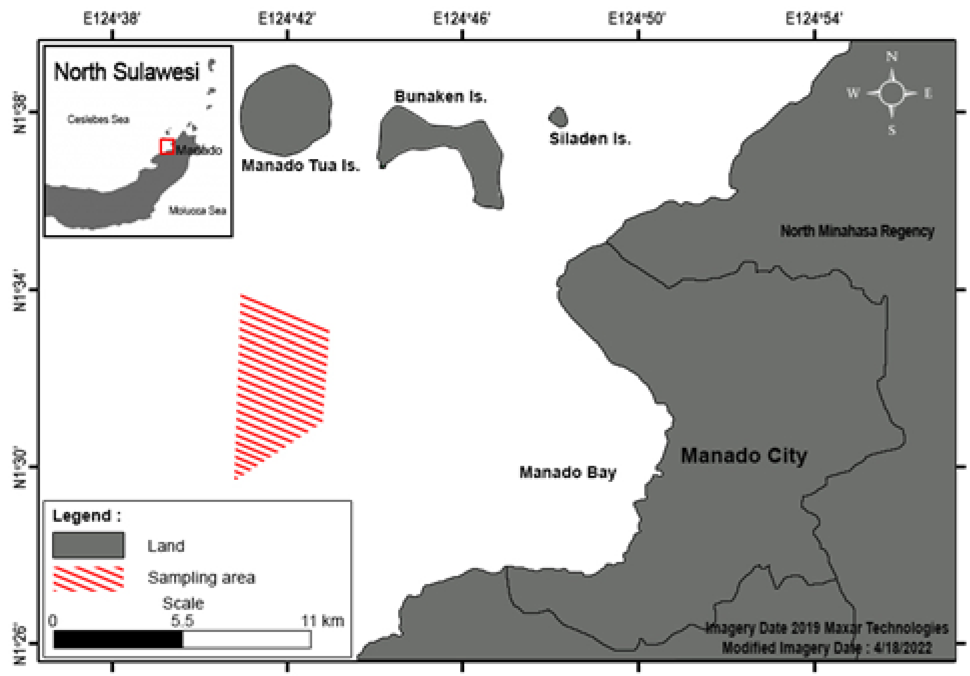


Figure 2. Sampling site

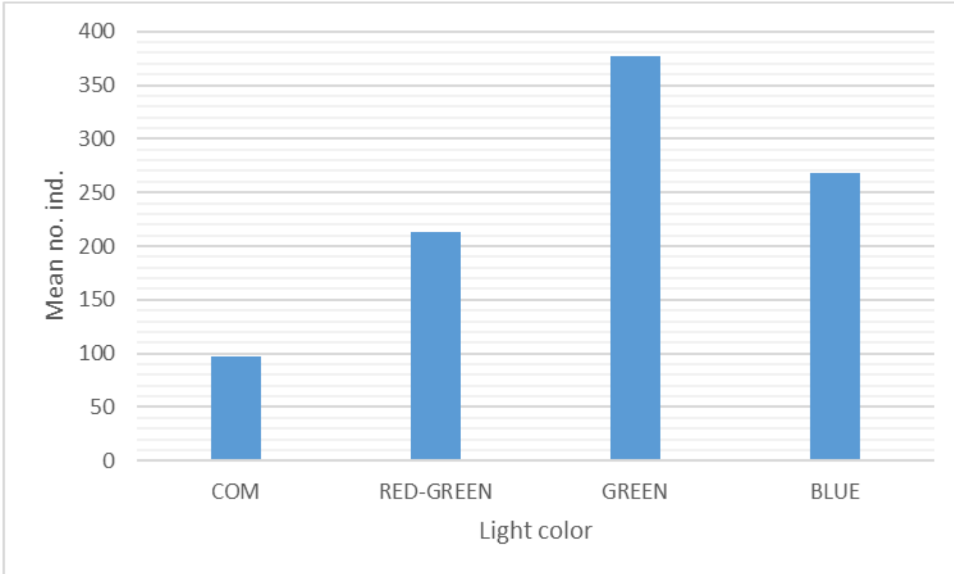


Figure 3. Mean catch of squid *S. oualaniensis* during the study.

Fisheries and Aquatic Sciences
Indexed in SCOPUS and KCI
eISSN : 2234-1757

Home (/) Author (/author/) Login: Silvester Benny Pratasik My page (/my) Logout (/auth/logout)

Submission

1. Manuscript Type & Category (/author/submit_article_type?ar_id=432)
2. Title & Abstract (/author/submit_title?ar_id=432)
3. Author (/author/submit_author?ar_id=432)
4. Additional Information (/author/submit_cover_letter?ar_id=432)
5. Respond to Review (/author/respond_to_review?ar_id=432)
6. File Upload (/author/submit_file_upload?ar_id=432)
7. Submission Preview (/author/submit_preview?ar_id=432)

Manuscript Type & Category

Select the Article Type or Category related to your manuscript. If you want a process of urgency, you may need to pay additional charge according as the term of Journal.

Submission Previous Summary

You can check the previous submission and the review results clicking the button below.

Close Details of 1st Submission

Manuscript Information

Manuscript ID	fas-2022-0089
Degree (Date submitted)	1st (2022-08-15)
Status (Date changed)	Process ended (2022-10-19)

Manuscript Type & Category

Urgency	Normal Manuscript
Type	Research Article
Category	Ecology and Fisheries Resource Management

Title & Abstract

Title (English)	Behavioral Response of Purpleback Flying Squid Sthenoteuthis oualaniensis (Mollusk; Cephalopod) to the Flashlight Artificial Bait Colors
Running Title (English)	Effect of bait color on squid's feeding rate
Abstract (English)	This study aimed to the response of deep-sea squid *Sthenoteuthis oualaniensis* to the light colors of the artificial bait. This experiment used the commercial artificial flashlight baits commonly sold in the fishing shop. The bait has several different light color combinations. The light colors were modified into several light colors by inactivating certain colors and used as treatments. We applied red-green, green, blue, and commercial bait lights in this study. Each treatment has 3 replications. The effect was expressed as the amount of squid caught. Data were analyzed by One-Way ANOVA. Results showed a significant effect on the number of squid catches. There was significantly different squid catches among the treatments. It indicates that this artificial flashlight bait could be developed to maximize squid catches.
Keywords (English)	commercial jig; modification; effect; catch

Author Information

Author	Silvester Benny Pratasik [first_author] , Lefrand - Manoppo, Effendi P. Sitanggang, Lusia - Manu
Affiliation	[1] Fisheries Resources Management, Faculty of Fisheries and Marine Sciences, Sam University, Jl. Kampus Bahu, Manado 95115, Indonesia [2] Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Jl. Kampus Bahu, Manado 95115, Indonesia [3] Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Jl. Kampus Bahu, Manado 95115, Indonesia [4] Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Jl. Kampus Bahu, Manado 95115, Indonesia
Corresponding Author	Silvester Benny Pratasik (spjong07@yahoo.com, office: +62 431 6868027, mobile: +62 81356221375)
Author Information	Silvester Benny Pratasik (E-mail:spjong07@yahoo.com, office: +62 431 6868027, mobile: +62 81356221375) Lefrand - Manoppo (E-mail:lefrandmanoppo@unsrat.ac.id, office: +62 431 6868027, mobile: +62 8124425236) Effendi P. Sitanggang (E-mail:epstagg@unsrat.ac.id, office: +62 431 6868027, mobile: +62 8124413377) Lusia - Manu (E-mail:manulusia@unsrat.ac.id, office: +62 431 6868027, mobile: +62 81355038744)
ORCID	Silvester Benny Pratasik (https://orcid.org/0000-0002-3765-509X (https://orcid.org/0000-0002-3765-509X)) Lefrand - Manoppo (https://orcid.org/0000-0002-9154-4470 (https://orcid.org/0000-0002-9154-4470)) Effendi P. Sitanggang (https://orcid.org/0000-0002-0256-2950 (https://orcid.org/0000-0002-0256-2950)) Lusia - Manu (https://orcid.org/ https://orcid.org/0000-0001-6200-4451 (https://orcid.org/ https://orcid.org/0000-0001-6200-4451))

Additional Information

Cover letter	Dear FAS editor, I herewith send you a new article "Behavioral response of the deep-sea squid *Sthenoteuthis oualaniensis* (Mollusk; Cephalopode) to the flashlight artificial bait color" to publish in Fisheries and Aquatic Science journal. I hope thismanuscript could meet your requirements. Thank you Wishes, Silvester B. Pratasik Corresponding author
Funding information	No funder, but small research money from Sam Ratulangi University

Conflict of interest	This paper has no conflict of interest.
IRB/IACUC approval	No human and animal participants

Suggested & Opposed Reviewer

Name	ORCID	Email	Affiliation	Country	Type	Short Reason
John A Endler	https://orcid.org. 0000-0002-7557-7627--	walter.gratzer@gmail.com	Department of Zoology & Tropical Ecology, James Cook University, Townsville, QLD 4811, Australia	Australia	**Suggest**	same field of study
Seyed Yousef Paighambari	orcid.org/0000-0002-8893-9308	sypaighambari@yahoo.com	Fisheries Department, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran. 2Iranian Fisheries Organization, Tehran, Iran.	Iran, Islamic Republic of	**Suggest**	same field of study

File Upload

Order	Item	File Name	File Size	Description	Last modified date
1	Manuscript File (with Author Details)	fas-2022-0089-MAN-Behavioral_Response_of_Squid_to_the_Flashlight_Artificial_Bait_Color-FAS.doc (/func/download_file?file_name=64bb87c5dd52adf820b310e766ceb06d.doc&file_path=../uploads/author/381/&orig_name=fas-2022-0089-MAN-Behavioral_Response_of_Squid_to_the_Flashlight_Artificial_Bait_Color-FAS.doc)	69KB	manuscript	Aug 15, 2022
2	Copyright Transfer Agreement	fas-2022-0089-COP-Copyright_transfer_agreement.pdf (/func/download_file?file_name=4920e399999ab3170751654da4217938.pdf&file_path=../uploads/author/381/&orig_name=fas-2022-0089-COP-Copyright_transfer_agreement.pdf)	217KB	Copyright Transfer Agreement	Aug 15, 2022
3	Table Files	fas-2022-0089-TAB-Table_1.docx (/func/download_file?file_name=f763eeccc77925e719559302c66354b8.docx&file_path=../uploads/author/381/&orig_name=fas-2022-0089-TAB-Table_1.docx)	12KB	Table 1	Aug 15, 2022
4	Table Files	fas-2022-0089-TAB-Table_2.docx (/func/download_file?file_name=47e9ba47a4926664a44d6e2be0fa4a09.docx&file_path=../uploads/author/381/&orig_name=fas-2022-0089-TAB-Table_2.docx)	12KB	Table 2	Aug 15, 2022
5	Figure Files	fas-2022-0089-FIG-Figure_1.docx (/func/download_file?file_name=d2219983178f847f58521716fafb0333.docx&file_path=../uploads/author/381/&orig_name=fas-2022-0089-FIG-Figure_1.docx)	85KB	Figure 1	Aug 15, 2022
6	Figure Files	fas-2022-0089-FIG-Figure_2.docx (/func/download_file?file_name=0cc239a9d9f73385f2be8c4ed2017101.docx&file_path=../uploads/author/381/&orig_name=fas-2022-0089-FIG-Figure_2.docx)	23KB	Figure 2	Aug 15, 2022

Review PDF : fas-2022-0089(1st).pdf (/func/download_review_pdf?ar_id=381)

Similarity Check Report

Similarity Check Score	Report	File Submission Date
26%	Link to report (https://api.ithenticate.com/view_report/D32B8AE0-5E2F-11ED-ACDC-11A23FE8B92A)	Aug 15, 2022

Related Article already Published

Google Scholar	Search through Manuscript's Title (https://scholar.google.co.kr/scholar?q=Behavioral Response of Purpleback Flying Squid Sthenoteuthis oualaniensis (Mollusk; Cephalop
PubMed	Search through Manuscript's Title (https://www.ncbi.nlm.nih.gov/pubmed/?term=Behavioral Response of Purpleback Flying Squid Sthenoteuthis oualaniensis (Mollusk; Cephal

Completed Review List

Review 1

File to Author	No data saved

Review 2

File to Author	fas-2022-0089-RVW-fas-2022-0089-MAN-1_Review.pdf (/func/download_file?file_name=5592e3d61928272ab0d56e1b23e16a6b.pdf&file_path=../uploads/review/381/&orig_name=fas-2022-0089-RVW-fas-2022-0089-MAN-1_Review.pdf) (506.55KB) (This file can be downloaded by the author.)

Review 3

File to Author	No data saved

Editor's Recommendation

Comment to Author *

Reviewer 1:

I am certain that it will be revised to be accepted with more analysis in results, however, I hope to recommend this paper can be accepted for publication.

Reviewer 2:

The purpose of this paper is to find out the most effective artificial baits for baits with different colors in squid jigging fishery.

However, the sea trial method of this study is not clear and the reproducibility of the test results is insufficient.

In addition, data on the analysis of test results are insufficient, and statistical analysis is also considered to be necessary again.

Therefore, it is judged that the current manuscript cannot be published as a thesis in this journal due to lack of data and errors in the test method, and it is judged that supplementation of the data and description of the test method are necessary again.

Reviewer 3:

This paper result is very helpful for squid fisherman. And, for better understanding, you have to insert artificial bait picture. In Results, 3rd paragraph Figure 1 -> Figure 2.

File No data saved

Editor-In-Chief's Decision

Comment to Author *	Thank you for your submission. Revise and send us revised-version, as soon as possible.
File	No data saved
Final Decision	**Minor revisions**

Urgency * (selected) Normal Manuscript ( ) **Fast-track** Manuscript

Article Processing Charge (http://www.e-fas.org/author/charge)

Fast-track Information (http://www.e-fas.org/author/charge)

Type * Research Article

Category *

- ○ Marine Biotechnology
- ○ Environment and Taxonomy
- ○ Aquaculture
- ○ Fish Immunology and Pathology
- ◉ Ecology and Fisheries Resource Management
- ○ Food Processing
- ○ Nutrition and Physiology
- ○ Molecular Biology and Genetics
- ○ Special Issue: Blue Biotechnology

Special Issue Information (http://www.e-fas.org/archive/special_issue)

Save | Save & Next

Fisheries and Aquatic Sciences

Pukyong National University, 45 Yongso-ro, Nam-gu, Busan 48513, Korea
TEL: +82-51-629-7363, FAX: +82-51-626-1039, Email: kosfas@kosfas.or.kr (mailTo:kosfas@kosfas.or.kr)

Response to Reviews

We would firstly thank all comments on this paper. We have checked and added some additional information to give a better understanding of how the experiment was done.

Reviewer 1: The paper has been revised by adding some information in either method or result part. We put all revisions in Red.

Reviewer 2: The purpose of this paper is to find out the most effective artificial baits for baits with different colors in squid jigging fishery.

We have realized that this study was so simple experimental study and focuses only on the effect of the light color or the artificial bait. Therefore, the use of 10 fishing trips is considered enough to explain the response of the squid to the flashlight, since we used the catch data as a response parameter. We did not include the environmental factors that might influence the squid catches, because we assume that the squid population is evenly affected by environmental factors. In this case, we have put some additional information to explain the results.

Reviewer 3: We put the artificial bait picture in Figure 2 with additional information on how the squids were caught (RED).

Yukiko Yamashita
Graduate School of Fisheries Science and Environmental Studies, Nagasaki University, 1-14 Bunkyo, Nagasaki 852-8521, Japan. orcid: 0000-0001-5441-0216 E-mail addresses: yukko 27@hotmail.com

Luiz Felipe R. B. Toledo (0000-0003-0788-3291) - ORCID

Museu de Zoologia “Prof. Dr. Ad˜ao Jos´e Cardoso”, Instituto de Biologia, UniversidadeEstadual de Campinas,Rua Albert Einstein s/n, CP 6109, 13083-863 Campinas, SP, Brazil

- *UğurAltınağaç*: *Orcid* 0000-0002-3638-9834, Researcher at ÇanakkaleOnsekiz Mart Üniversitesi Turkey; Correspondent: ualtinagac@yahoo.com

Turkey
Yoshiki MATSUSHITA
Graduate School of Fisheries Science and Environmental Studies, Nagasaki University,Nagasaki, 852-8521, Japan1314151617* Corresponding author. Tel.: +81 95 819 2803; fax.: +81 95 819 280318E-mail address: yoshiki@nagasaki-u.ac.jp (Y. Matsushita).19

Requesting to revise your manuscript. (fas-2022-0089)

From: Fisheries and Aquatic Sciences (no_reply@guhmok.com)

To: spjong07@yahoo.com

Date: Monday, January 16, 2023 at 05:44 PM GMT+8

Fisheries and Aquatic Sciences
Indexed in SCOPUS and KCI
eISSN : 2234-1757

Manuscript ID : fas-2022-0089 (2nd)
Manuscript Type : Research Article
Manuscript Subarea : Ecology and Fisheries Resource Management
Manuscript Title : Behavioral Response of Purpleback Flying Squid Sthenoteuthis oualaniensis (Mollusk; Cephalopod) to the Flashlight Artificial Bait Colors

Dear Dr. Silvester Benny Pratasik

This is Fisheries and Aquatic Sciences.

The examination of your manuscript has been completed.
The editor-in-chief had made a final decision that the revision were needed.
You can check the comments below by accessing the online submission system.
Even if there is some files attached by the reviewers, you can not check it in the e-mail, so please make sure to access the system.
After reflecting the correction in the manuscript, be sure to submit it again using the submission system.

Editor's comment to author:

Reviewer 1:

I think that the construction of the MS is appropriated so that I recommend the MS will be accepted in the Journal of Fisheries and Aquatic Sciences.

Reviewer 2:

This thesis has been faithfully revised for the items reviewed in the first review.

In addition, each Fig. Please format the form according to the submission guidelines of this journal. Also, please explain the meaning of the abbreviated terms in Fig.

Reviewer 3:

This paper describes the response of deep-sea squid *Sthenoteuthis oualaniensis* to the light colors (Red-Green, Blue, Green, and Red) of the artificial bait. The strength of the study can be more emphasized especially in the abstract and discussion sections and the paper would benefit from a careful revision of the discussion. Below are some comments and suggestions for the authors to consider.

Editor-in-chief's comment to author:

Please do not reply to this e-mail message. If you have comments or questions, please use the contact information below.

If this email is in the spam folder, please classify this email as non-spam to receive other emails safely.

Best regards,
You-Jin Jeon, Jung Hwa Choi, Han Kyu Lim, and Suengmok Cho, Editors-in-Chief
Fisheries and Aquatic Sciences

Fisheries and Aquatic Sciences

- Address: Pukyong National University, 45 Yongso-ro, Nam-gu, Busan 48513, Korea
- Phone: +82-51-629-7363
- Email: kosfas@kosfas.or.kr
- Homepage : https://submission.e-fas.org/

Table 1. ANOVA on the effect of artificial bait light colors on the number of catches.

Source of Variance	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Main Effects					
A: Trip	85653.0	9	9517.0	24.96	0.0000
B: Bait light color	$1.22351*10^{-6}$	3	407836.	1069.59	0.0000
A-B interactions	16791.1	27	621.892	1.63	0.0488
RESIDUAL	30504.0	80	381.3		
TOTAL	$1.35646*10^{-6}$	119			

Table 2. Multiple comparisons between treatment applications.

Bait light color comparisons	Difference	+/- Limits
BLUE – COM	171.167*	13.229
BLUE – GREEN	-109.067*	13.229
BLUE – RED-GREEN	54.8667*	13.229
COM – GREEN	-280.233*	13.229
COM – RED-GREEN	-116.3*	13.229
GREEN – RED-GREEN	163.933*	13.229

Note: * - significant difference

Fisheries and Aquatic Sciences
Indexed in SCOPUS and KCI
eISSN : 2234-1757

Journal Title:	Fisheries and Aquatic Sciences
Manuscript ID:	fas-2022-0089
Degree (Date created):	3rd (2023-01-24)
Manuscript Title:	Behavioral Response of Purpleback Flying Squid Sthenoteuthis oualaniensis (Mollusk; Cephalopod) to the Flashlight Artificial Bait Colors
Running Title:	Effect of bait color on squid's feeding rate
Urgency:	Normal Manuscript
Type:	Research Article
Category:	Ecology and Fisheries Resource Management;
Respond to review:	Response to Reviewers

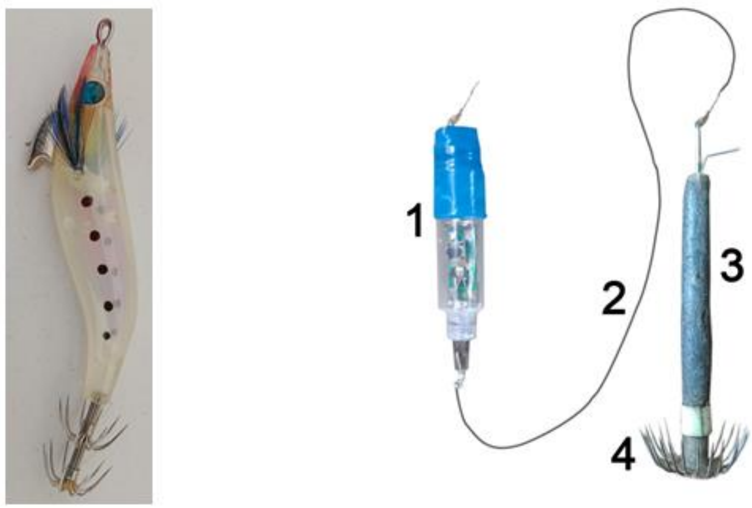
Dear Reviewers,

I would first thank you for commenting on our manuscript until this stage. We have changed the paper following the picture format of FAS. We also add short information to show the strength of the study. All revisions are given in Red. We hope that it could fulfill the requirements.

Wishes,

Silvester B. Pratasik

Corresponding author



(a) (b)

Fig. 1. Artificial bait. (a) shrimp-like bait and (b) flashlight jig.

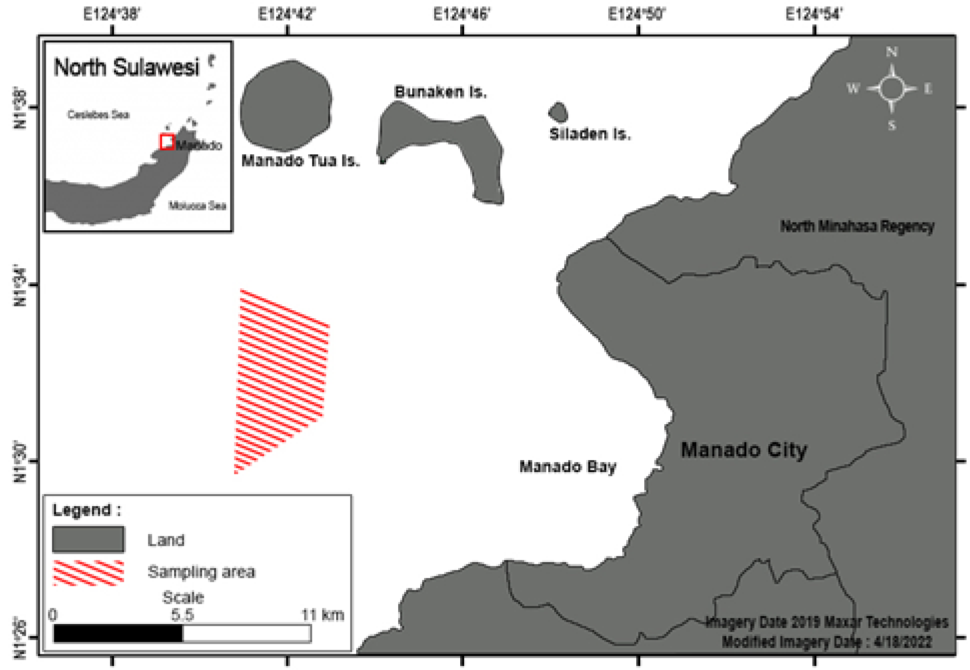


Fig. 2. Sampling site

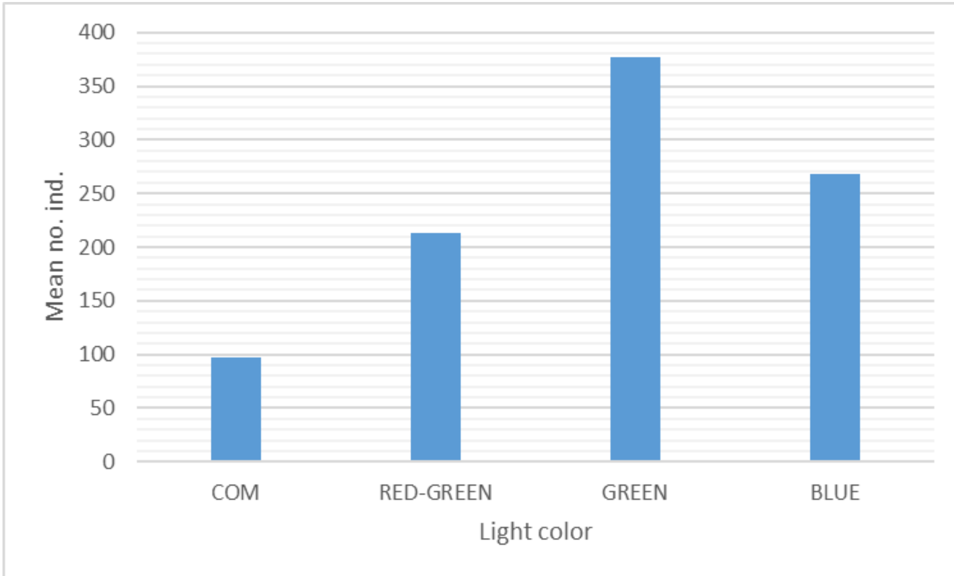


Fig. 3. Mean catch of squid *S. oualaniensis* during the study.

Table 1. ANOVA on the effect of artificial bait light colors on the number of catches.

Source of Variance	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Main Effects					
A: Trip	85653.0	9	9517.0	24.96	0.0000
B: Bait light color	$1.22351*10^{-6}$	3	407836.	1069.59	0.0000
A-B interactions	16791.1	27	621.892	1.63	0.0488
RESIDUAL	30504.0	80	381.3		
TOTAL	$1.35646*10^{-6}$	119			

Table 2. Multiple comparisons between treatment applications.

Bait light color comparisons	Difference	+/- Limits
BLUE – COM	171.167*	13.229
BLUE – GREEN	-109.067*	13.229
BLUE – RED-GREEN	54.8667*	13.229
COM – GREEN	-280.233*	13.229
COM – RED-GREEN	-116.3*	13.229
GREEN – RED-GREEN	163.933*	13.229

Note: * - significant difference

Response to Reviewers

Dear Reviewers,

I would first thank you for commenting on our manuscript until this stage. We have changed the paper following the picture format of FAS. We also add short information to show the strength of the study. All revisions are given in Red. We hope that it could fulfill the requirements.

Wishes,

Silvester B. Pratasik
Corresponding author

Behavioral Response of Purpleback Flying Squid *Sthenoteuthis oualaniensis* (Mollusk; Cephalopod) to the Flashlight Artificial Bait Colors

Lefrand Manoppo[1)], Silvester B. Pratasik [2)], Effendi P. Sitanggang[1)], Lusia Manu[2)], Juliaan C. Watung[3)]

[1)]Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Jl. Kampus Bahu Manado-95115, North Sulawesi, Indonesia; [2)]Fisheries Resources Management, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Jl. Kampus Bahu Manado-95115, North Sulawesi, Indonesia; [3)]Aquaculture, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Jl. Kampus Bahu Manado-95115, North Sulawesi, Indonesia. Corresponding author: S.B. Pratasik, spjong07@yahoo.com

ABSTRACT. This study aimed to know the response of deep-sea squid *Sthenoteuthis oualaniensis* to the light colors of the artificial bait. This experiment used the commercial artificial flashlight baits commonly sold in the fishing shop. The bait has several different light color combinations. The light colors were modified into several light colors by inactivating certain colors and used as treatments. The study is expected to be able to find flashlight bait's most effective color for squid fishing. We applied red-green, green, blue, and commercial bait lights in this study. Each treatment has 3 replications. The effect was expressed as the amount of squid caught. Data were analyzed by One-Way ANOVA. Results showed a significant effect on the number of squid catches. There was significantly different squid catches among the treatments. It indicates that this artificial flashlight bait could be developed to maximize squid catches. This finding could be used for the local fishermen's income and the squid fisheries development.

Keywords: commercial jig, modification, effect, catch.

Introduction

The exploitation of fisheries resources starts from a basic human need to obtain animal protein sources. Squid is one of the protein sources from the ocean, and nearly all body parts are edible. Since 1950, capture production of cephalopods has continued to grow (Hunsicker et al., 2010; Doubleday et al., 2016), with total commercial annual catches between 3.5 and 4.9 million tons in 2008–2017 (FAO, 2019), almost 4.6 times higher than that of the 1950s. Cephalopods on average support approximately 15 and 20% of marine fishery landings and landed values, respectively (Hunsicker et al., 2010; FAO, 2019). This group has unique life history characteristics, including rapid growth, short lifespan, and semelparous reproductive strategy, giving them both sensitivity and resilience to anthropogenic exploitation and oceanographic variability (Rodhouse et al., 2014). The species within the family Ommastrephidae support approximately 33.8% of the global cephalopod's landings (FAO, 2019). This group is recognized as voracious and adaptable predators of a broad range of prey including small crustaceans and fishes at early life stages and shift to micronekton, larger fishes, and cephalopods (including cannibalism) as they grow (Nigmatullin et al., 2001; Alegre et al., 2014). Despite its economic importance, the offshore oceanic squid resources' exploitation rate is relatively low (Worms, 1983). The flying squids (Ommastrephidae; Oegopsid) cover about 65% of the world's commercial cephalopods (Roper et al. 1984; Brunetti 1990) with a total of about 2.6 million in 1991 (FAO 1993). The flying squids *Sthenoteuthis oualaniensis* (Lesson) and *Ommastrephes bratamii* are the oceanic species of this family that are distributed from the Indo-Pacific to the Indian Ocean. According to Voss (1973), the potential of the purpleback flying squids in the Central Eastern Pacific is at least 100,000 metric tons. This species is caught commercially in the eastern and southern East China Sea, from Taiwan to Okinawa by hook and line with light at night (Yoshikawa 1978; Okutani 1980; Tung 1981,). The deep-sea squids caught by traditional fishermen of Manado Bay, North Sulawesi, in the Sulawesi Sea have been identified as a dwarf form of *Sthenoteuthis oualaniensis* (Pratasik et al., 2022). These species are highly migratory and undertake diel vertical migrations of several hundred meters and seasonal migrations between the shelf and open ocean (Gilly et al., 2006; Stewart et al., 2013) so that they can act as important linkages between both neritic and oceanic food webs (Arkhipkin, 2013).

There are numerous studies on bait types to find the highest catch, from fish and shrimp flesh, live bait, and artificial bait. Fish and **s**quids were observed to be attracted to squid jigging vessels due to the phototaxis (Rao. 1996). It is related to their behavior to avoid predators or enhance feeding efficiency (Solomon and Ahmed, 2016), and their response depends upon species, ontogenic development, light source characteristics, intensity, color, and wavelength (Mallawa et al., 1991). Therefore, fishermen catch squid using light that illuminates in water as well as jigs to attract the squids to aggregate and bite the jigs (Asokan and Krishnan, 2021). It relies on the artificial bait of shrimp-like siliconized jig fishing (Altinagac, 2006; Ulas & Aydin, 2011; Paighambari et al., 2012; Reza et al., 2019**;** Aydin & Ilkyaz, 2021**).** Other studies on hand-line fishing are also done using different colors of shrimp-shaped jigs (Altinagac, 2006; Ulas & Aydin, 2011; Paighambari et al., 2012; Aydin & Ilkyaz, 2021). Squid fishing in North Sulawesi is done by traditional fishermen using 5 to 7 M-boat and artificial bait either shrimp-like bait or other bait types (Fig. 1).

Fig. 1. Artificial bait. (a) shrimp-like bait and (b) flashlight jig: 1) flashlight; 2) one-meter line; 3) lead; 4) hook.

For deep-sea squid *S. oualaniensis* fishing, the fishermen use a mini-battery-supported flashlight artificial bait sold in the fishing stores. The flashlight artificial bait contains several different alternately blinking light colors to get the squid to bite. This study modifies the light colors to find the best modification of light color against the catches.

Method

This study was carried out from June to July 2020. Traditional fishermen catch deep-sea *squids S. oualaniensis* in the Sulawesi Sea, North Sulawesi, at night (Fig. 2). The flashlight bait is facilitated with a mini-battery to be able to produce several different light colors to attract the squid. The flashlight was connected by a one-meter line to the hook working also as a lead. In fishing operations, the lead was coated with fish flesh as bait.

This experiment modified the standard commercial flashlight bait sold in the fishing shop to produce different light colors: Red-Green, Blue, Green, and Red. These different light colors were used in 10 fishing trips. Twelve skillful fishermen were used in this experiment in which they were divided into 4 groups of 3 people in 4 separate traditional boats (7 m long) to operate each light color in the same fishing ground. The common commercial flashlight bait was also used as a control treatment. Each line used only one jig and all jig-fishing activities were carried out at the same time. The fishing line was lowered down to the depth range of 20-25 M in the deep sea of Sulawesi Sea waters and jigged. This fishing depth is consistent with the dispersal range peak of *S. oualaniensis* (Jerep and Ropper, 2010).

Fig. 2. Sampling site.

The use of the red-colored bait was eventually terminated because it was always cut off and lost. The experiment utilized only commercial bait, red-green bait, blue bait, and green bait as treatment with 3 replications represented by 3 local skillful fishermen for each bait light color. Data collections were squid catches. The catch data were analyzed with one-way ANOVA facilitated by statistical software for comparisons. The difference between treatments was then tested using Tukey's Honestly Significant Difference (HSD) procedure.

Results

This study caught a total of 30,687 squids *S. oualaniensis* during the fishing experiment in the Sulawesi Sea, North Sulawesi. Different light color applications highly significantly influenced the number of squid catches ($P<0.001$). Analysis of Variance demonstrates that both trip and bait light color influence the squid catches (Table 1).

Table 1. ANOVA on the effect of artificial bait light colors on the number of catches.

Tukey's Honestly Significant Difference (HSD) test revealed that *S. oualaniensis* differently responded to the bait's light colors. All treatment applications gave a significantly different number of catches. Comparisons between treatments showed that all bait light color modifications gave a higher number of catches than the commercial one (Table 2).

Table 2. Multiple comparisons between treatment applications.

The significantly different squid catches are also indicated by the mean number of squid catches (Fig. 3). The green-lighted jig yielded the highest mean squid catches, 377.37 (39.46%), followed by blue light color, 268.3 (28.06%), then red-green, 213.43 (22.32%), and the lowest catches in the commercial artificial bait, 97.13 (10.16%) (Table 2 and Fig. 3). Multiple comparisons between treatment applications yielded 6 pairs of comparisons and indicated that all treatment flashlight jig colors yielded significantly different squid catches, in which single light colors also give the squid a higher response to taking the lure (Table 2).

Fig. 3. Mean catch of squid *S. oualaniensis* during the study.

Discussion

Jigging is an essential fishing method to exploit squids selectively and avoid overexploiting to conserve resources and energy (Asokan & Krishnan, 2021). It helps to adjust operational depth according to the concentration depth of squids. They are attracted to lights and fast-moving bait or any bait-like object. A typical jig consists of a shrimp or stalk-like body made of flexible plastic with one to three hooks or more sharp barbless steel hooks at the end. Other jigs are facilitated with the mini battery-supported light blinking.

Squids are known as color-blinded animals, but the degree of contrast is important for squid behavior to attack the jig (Flores et al., 1978). The use of a flashlight jig, in fact, gave a stronger degree of contrast in the water column at night fishing than the use of light above the water and could give a stronger stimulus to the squid to attack the fish flesh bait connected to blinking light. The flashlight jig also has a higher degree of contrast than the shrimp-like siliconized jig so that the squid more sensitively responds to the flashlight jig color in the water column. The flashlight acts as a squid-aggregating device, while the squid feeds on the fish's flesh, then caught by the hook. The flashlight jig could help the purpleback flying squid get the bait. All squids were hooked on the arms, indicating that the squids are feeding on the fish's flesh coated on the lead. On the other hand, cephalopods (squid, cuttlefish, and octopus) are well known as voracious predators of many preys, such as fish and crustaceans, or even have cannibalism behavior, so the contrast moving objects in the water column could indicate the presence of moving prey.

Furthermore, the present study revealed that the modified light colors of the artificial bait caught a higher number of deep-sea squid *S. oualaniensis* in the Sulawesi Sea than the common commercial artificial bait sold in the fishing store with a combination of several different colors. There was also a significantly different effect of all light color modifications on the squid catches with the highest catch in the green light. The low attacking preference of the purpleback flying squid to the multiple light colors could result from the squid's perception of the blinking multiple colors of the flashlight bait as the aposematic coloration of the prey, in which the animal shows the unpalatability or toxicity through warning coloration. This defense mechanism is widely discussed by Endler (1978), Mappes et al (2005), Mochida et al (2015), Stevens (2007), and Toledo & Haddad (2009). Aposematism is commonly found across the animal kingdom as a defense mechanism, and it could either be chemicals, such as toxins, harmful secretions, and venoms, or physical defense, such as spines, bites, and stings (Mappes *et al*., 2005).

This finding is in agreement with Altinagac (2006) and Paighambari et al (2012) that the green bait color is more efficient in squid jig fishing even though it does not have a significantly different effect from the use of red color in Turkish waters (Altinagac 2006) and the blue color (Paighambari et al., 2012) on the catch rate of purpleback flying squids in Iranian waters of the Oman Sea. The sensitivity of fish and some of their food animals to blue and green colors is higher because of the long wavelengths that make them penetrate deeper into the water column (Solomon & Ahmed 2016). The use of dark green jig color is also shown by the traditional fishermen, particularly in North Minahasa, North Sulawesi, as a potential bait color for demersal fish jig fishing (field obs.). Nevertheless, Ulaş and Aydin (2012) found that the red jig is the most efficient in squid *Loligo vulgaris* Lamarck (1798) fishing on the Middle Eastern Coast of Aegean Sea, Turkey. All those findings were obtained using the shrimp-like siliconized bait. The local fishermen of North Sulawesi commonly use the shrimp-like siliconized jig to fish shallow water squids *Sepioteuthis lessoniana.* A different finding is shown by Arnupapboon et al (2008) that the squid moves to white and blue more often than green, while the red color seemed not to attract the squids.

This fishing experiment reconfirms the previous finding concerning the most efficient bait color and shows that the use of single bait light color yielded higher catches than that of multiple colors ($P<0.05$). This study did not use the red light color as a treatment, since the red-lighted bait was always taken and cut off. Therefore, we had to use a wireline to the bait to know what causes the loss and found that the red light color was taken by the cutlassfish *Trichiurus* sp. The difference in squid's preference for jig color could result from environmental conditions with locality, such as predator-prey interactions that may alter the feeding behavior on-site and species. The presence of a higher level of the predator, such as cutlassfish *Trichiurus* sp, particularly in Sulawesi waters which is also attracted to the red-light jig has diminished the chance of the deep-sea squids *S. oualaniensis* to take the red jig or the squid *S. oualaniensis* is vulnerable to predation risk for feeding on the red-light jig.

According to Asokan and Krishnan (2021), the efficiency of squid jigging is influenced by jig structure, jigging motion, light intensity, sea state, and sea surface temperature (Cabanellas-Reboredo et al., 2012; Roberts and Sauer, 1994; Yu et al., 2015), wind speed, moon phase, and atmospheric pressure (Cabanellas-Reboredo et al., 2012), sea surface height anomaly (Yu et al., 2015), turbidity (Roberts and Sauer, 1994), chlorophyll (Hurst et al., 2012), salinity (Yu et al., 2015), and large scales climate predictors, such as the Southern Oscillation Index (SOI) and the North Atlantic Oscillation (NAO) (Roberts and Sauer, 1994; Morales-Bojorquez et al. 2001; Pierce et al., 2006). etc. These factors will influence the catches, recruitment, migration (Koopman et al (2018), and distribution of the squids. During squid jigging with lights, the quality of light (e.g. wavelength), the quantity of light (e.g. power), and the arrangement of fishing lights affect the squid's attraction. These factors create underwater irradiance levels and distribution influenced by the optical characteristics of seawater, and it influences squid behavior during fishing (Arakawa et al., 1998; Yamashita et al., 2012). According to Cabanellas-Reboredo et al. (2012), environmental variables, such as sea surface temperature, atmospheric pressure, and moon cycle can also influence squid catches. This experiment focused only on the effect of different jig light colors on the squid bites since the fishing was conducted in a single lunar cycle with different tide conditions. The jiggers took advantage of wind or current direction to position their boats in certain areas to avoid being drifted too far out of the mainland due to the use of the small boat (approximately 5-7 M long).

These findings showed that all light color modifications of the multiple flashlight-squid baits have contributed to the artificial squid flashlight bait development concerning the squid fishing effectivity. Light colors also influenced the feeding behavior of *S. oualaniensis*, and the single color gave the squid a higher response to getting the lure than the multiple colors. The highest squid catch was recorded in the green light color and the lowest was in the commercial artificial bait. Therefore, the present study has contributed to developing the mini-battery-supported artificial bait for effective exploitation to maximize offshore squid production and fisheries development so that the use of offshore squid resources could rise. This information is also useful for traditional fishermen to increase their personal income through deep-sea squid fishing. Nevertheless, more studies on squid feeding behavior and other influencing environmental factors are needed for future squid population sustainability.

Competing Interests

This article has no competing interests.

Acknowledgments

We would greatly appreciate the Rector of Sam Ratulangi University and the Dean of the Faculty of Fisheries and Marine Sciences who provided a small research grant. High appreciation is also addressed to Mr. Ponny Telleng who led the local fishermen of Manado Bay in fishing operations.

References

Altinagac U. Effect of jigs color on catching efficiency in squid fishing in Turkey. Pakistan J. Biological Science 2006;9(15):2916-2918.

Arakawa H, Choi S, Arimoto T, Nakamura Y. Relationship between underwater irradiance and distribution of Japanese common squid under fishing lights of a squid jigging boat. Fisheries Science 1998;64:553-557.

Arkhipkin AI. Squid as nutrient vectors linking Southwest Atlantic marine ecosystems. Deep. Res. Part II Top. Stud. Oceanogr. 2013;95:7–20. DOI: 10. 1016/j.dsr2.2012.07.003.

Arnupapboon S, Awaiwanont K, Anongponyoskun M, Annanpongsuk S, Chokesanguan B. Boosting the development of responsible squid light fishery. Assessment of squid feeding behavior Southeast Asian Fisheries Development Center. Fish for the people 2008; 6(1):44-47 2008

Asokan K, Krishnan AR. Techniques to squid jigging in India: A review. J. Entomology and Zoology Studies, 2021;9(3):415-422. DOI: https://doi.org/10.22271/j.ento.2021.v9.i3f.8743

Aydin C, İlkyaz A. Catching performance and catching efficiency of siliconized baits in handline fishery. Journal of Agricultural Sciences (Tarim Bilimleri Dergisi) 2021;27(2): 219-230 DOI: 10.15832/ankutbd.606513

Brunetti NE. Description of *Rhynchoteuthion* larvae of *Illex argentinus* from summer spawning subpopulation. J. Plankton Res. 1990;12:1045-1057.

Cabanellas-Reboredo M, Alo´s J, Palmer M, Morales-Nin B. Environmental effects on recreational squid jigging fishery catches. ICES Journal of Marine Science 2012;69(10): 1823–1830. doi:10.1093/icesjms/fss159

Doubleday, ZA., Prowse TAA, Arkhipkin, A, Pierce GJ, Semmens J, Steer M., et al. Global proliferation of cephalopods. Curr. Biol. 2016;26:387–407. DOI: 10.1016/j.cub.2016.04.002. FAO (2019).

Endler JA. A predator's view of animal color patterns. In Hecht MK, Steere WC, Wallace B, editors. Evolutionary Biology volume 11, 1978. p. 319-364.

FAO Yearbook: Fishery and Aquaculture Statistics 2017. Rome: Food and Agriculture Organization of the United Nations.

Flores EEdC, Igarashi S, Miiumi T. Studies on squid behavior in relation to fishing III. On the optomotor response of squid, *Todarodes pacificus* Steenstrup, to various colors. Bull. Fac. Fish. Hokkaido Univ. 1978;29(2):131-140.

Gilly WF, Markaida U, Baxter CH, Block BA, Boustany A, Zeidberg, et al. Vertical and horizontal migrations by the jumbo squid *Dosidicus gigas* were revealed by electronic tagging. Mar. Ecol. Prog. Ser. 2006;324:1–17. DOI: 10. 3354/meps324001

Hunsicker ME, Essington TE, Watson R, Sumaila UR. The contribution of cephalopods to global marine fisheries: can we have our squid and eat them too? Fish Fish. 2010;11:421–438. DOI: 10.1111/j.1467-2979.2010.00369. x

Hurst RJ, Ballara SL, MacGibbon D, Triantafillos L. Fishery characterization and standardized CPUE analyses for arrow squid (*Nototodarus gouldi* and *N. sloanii*), 1989–90 to 2007–08, and potential management approaches for southern fisheries. New Zealand Fisheries Assessment Report 2012;47. 303 p

Jerep P, Roper CF. Cephalopods of the World. An Annotated and Illustrated Catalogue of Cephalopod Species Known to date, 2010; Vol. 2. Myopsid and Oegopsid. FAO, Rome.

Koopman M, Knuckey I, Cahill M. Improving the location and targeting of economically viable aggregations of squid available to the squid jigging method and the fleet's ability to catch squid. Australian Fisheries Management Authority. 2018;223 p.

Mallawa A, Palo SM, Musbir. Study on bagan Rambo fisheries in Barru waters, Makassar Strait. Research Report Project.Research Institute of Hasanuddin University. Makassar, (In Indonesian), 1991, 40p.

Mappes J, Marples N, Endler JA. The complex business of survival by aposematism. TRENDS in Ecology and Evolution, 2005; 20(11): 598-603.

Marchesan M, Spoto M, Verginella L, Ferrero EA. Behavioral effects of artificial light on fish species of commercial interest. Fish Res. 2005; 73:171-185.

Mochida K, Zang WY, Toda M. The function of body coloration of the hai coral snake *Sinomicrurus japonicus boettgeri.* Zoological Studies, 2015, 54:33. 6p.

Morales-Borjorquez E, Cisneros-Mata, MA, Nevarez-Martinez MO, Hernandez-Herrera A. Review of stock assessment and fishery biology of *Dosidicus gigas* in the Gulf of California, Mexico. Fisheries Research 2001;54: 83-94.

Nigmatullin CM, Nesis KN, Arkhipkin AI. A review of the biology of the jumbo squid *Dosidicus gigas* (Cephalopoda: Ommastrephidae). Fish. Res. 2001;54:9–19. DOI: 10.1016/S0165-7836(01)00371-X

Okutani T, Tung IH. Reviews of biology of commercially important squids in Japanese and adjacent waters, I. Symplectoteuthis oualaniensis (Lesson). Veliger. 1987;21(1): 87-94

Paighambari SY, Daliri M, Memarzade M. The effects of jig color and depth variation on catch rates of purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1830) in Iranian Waters of the Oman Sea. World Journal of Fish and Marine Sciences. 2012;4(5): 458-461. DOI: 10.5829/idosi.wjfms.2012.04.05.6415

Pierce GJ, Begoña Santos M, MacLeod CD, Wang J, Valavanis V, Zuur A. Modeling environmental influences on squid life history, distribution, and abundance. The role of squid in open ocean ecosystems, 16-17 November 2006, Hawaii, USA.

Pratasik SB, Lalamentik LTX, Manoppo L, Budiman J. Deep sea squid in Sulawesi Sea, North Sulawesi Province, Indonesia. Biodiversitas. 2022;23(4):1774-1779. DOI: 10.13057/biodiv/d230408

Rao KS. Cephalopod fishing. In Proceedings of the Seminar on Fisheries-A Multibillion Dollar Industry, Madras, Aug 17-19, 1995 Aquaculture Foundation of India & The Fisheries Technocrats Forum. 1996: 12-20.

Reza FA, Umroh, Utami E. The effect of bait types on squid Loligo sp capture in Tuing waters, Bangka Regency. J. Aquatropica Asia. 2019; 4 (1):20-25. [In Indonesian].

Roberts MJ, Sauer WHH. Environment: the key to understanding the South African chokka squid (*Loligo vulgaris reynaudio* life cycle and fishery? Antarctic Science. 1994; 6(2): 249-258.

Rodhouse PGK, Pierce GJ, Nichols OC, Sauer WHH, Arkhipkin AI, Laptikhovsky VV, et al. Environmental effects on cephalopod population dynamics. Adv. Mar. Biol. 2014;67, 99–233. DOI: 10.1016/b978-0-12- 800287-2.00002-0

Roper CEF, Sweeney MJ, Nauen C. Cephalopods of the World, Vol.3, An annotated and illustrated catalog of species of interest to fisheries. FAO Fisheries Synopsis 1984; 125, Rome, 277pp.

Solomon OO, Ahmed OO. Fishing with light: Ecological consequences for coastal habitats. International Journal of Fisheries and Aquatic Studies 2016; 4(2): 474-483

Stewart JS, Gilly WF, Field JC, Payne JC. Onshore-offshore movement of jumbo squid (*Dosidicus gigas*) on the continental shelf. Deep. Res. II Top. Stud. Oceanogr. 2013;95: 193–196. DOI: 10.1016/j.dsr2.2012. 08.019

Toledo LF, Haddad CFB. Colors and some morphological traits as defensive mechanisms in Anurans. Int. J. Zoology, 2009; 12p.

Tung IH. On the fishery and biology of the squid, *Ommastrephes bartramii*, in the northwest Pacific Ocean. Rep.Inst.Fish.Biol., Taipei, 1981;3(4): 12-37.

Ulaş A, Aydin I. The effect of jig colors and lunar brightness on coastal squid jigging. African Journal of Biotechnology. 2011; 10(9):1721-1726. DOI: 10.5897/AJB10.1775

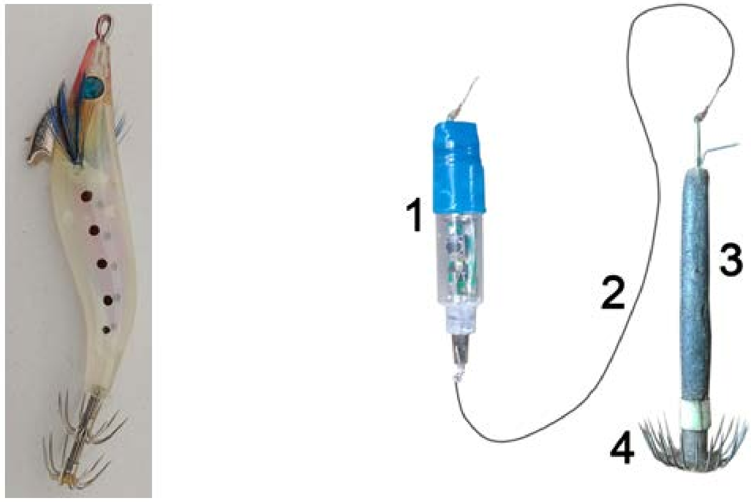
Voss, G. L., 1973. Cephalopod resources of the world. FAO Fish. Circ. 1973; 149: 75p.

Worms, J. World fisheries for cephalopods: A synoptic overview. In J. F. Caddy. 1983 (Ed.) Advances in Assessment of World Cephalopod Resources. FAO Tech. FAO. Rome. 1083; 231:1-20.

Yamashita Y, Matsushita Y, Azuno T. Catch performance of coastal squid jigging boats using LED panels in combination with metal halide lamps. Fisheries Research 2012;113:182-189

Yoshikawa N. Fisheries in Japan: Squid and Cuttlefish. Tokyo, Japan Marine Products Photo Materials Association. 1978; 161p.

Yu W, Chen X, Yi Q, Chen Y, Zhang Y. Variability of suitable habitat of western winter-spring cohort for neon flying squid in the Northwest Pacific under anomalous environments. PLoS ONE 2015;10(4): e0122997. doi:10.1371/journal. pone.0122997



(a) (b)

Fig.1. Artificial bait. (a) shrimp-like bait and (b) flashlight jig.

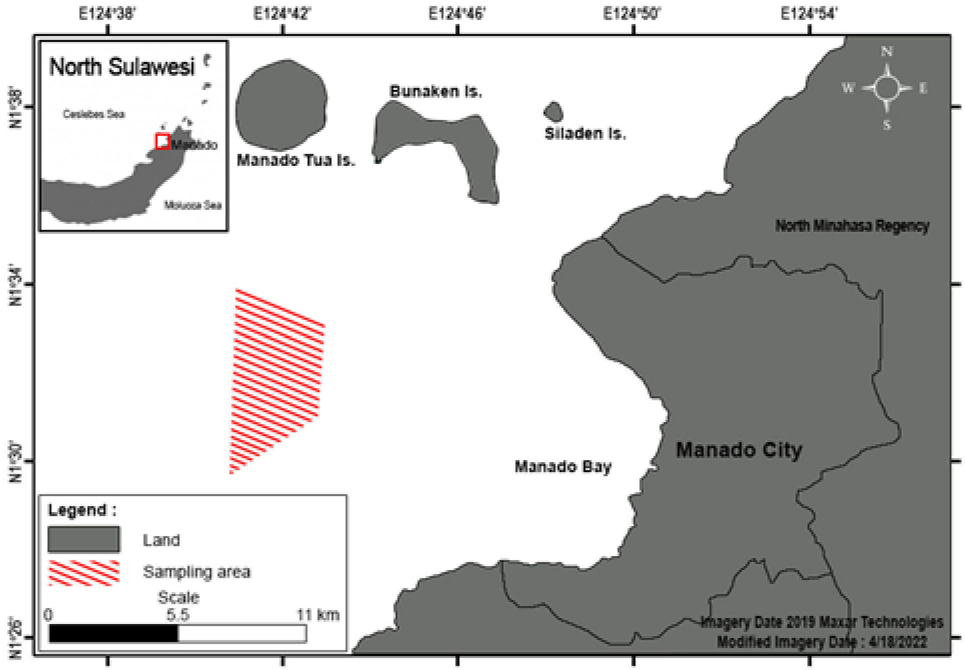


Fig. 2. Sampling site

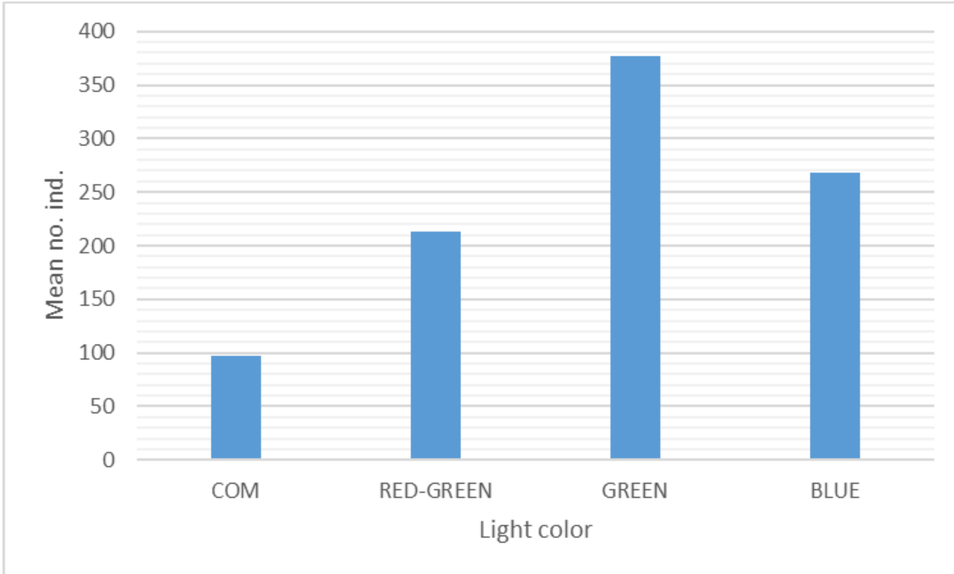


Fig.3. Mean catch of squid *S. oualaniensis* during the study.

Your manuscript has been accepted for publication (fas-2022-0089)

From: Fisheries and Aquatic Sciences (no_reply@guhmok.com)

To: spjong07@yahoo.com

Date: Thursday, January 26, 2023 at 08:41 AM GMT+8

Fisheries and Aquatic Sciences
Indexed in SCOPUS and KCI
eISSN : 2234-1757

Manuscript ID : fas-2022-0089 (3rd)
Manuscript Type : Research Article
Manuscript Subarea : Ecology and Fisheries Resource Management
Manuscript Title : Behavioral Response of Purpleback Flying Squid Sthenoteuthis oualaniensis (Mollusk; Cephalopod) to the Flashlight Artificial Bait Colors

Dear Dr. Silvester Benny Pratasik

This is Fisheries and Aquatic Sciences.

We are pleased to inform you that your work has now been accepted for publication.
. All manuscript materials will be forwarded to the publishing staff in the near future.
Please log in and check the review result.

Editor's comment to author:

I think that this MS is suitable to be revised to accept to this journal.

I hope you are doing well in your research.

Best wishes

Editor-in-chief's comment to author:

Thank you for your submission.

Please do not reply to this e-mail message. If you have comments or questions, please use the contact information below.

If this email is in the spam folder, please classify this email as non-spam to receive other emails safely.

Best regards,
You-Jin Jeon, Jung Hwa Choi, Han Kyu Lim, and Suengmok Cho, Editors-in-Chief
Fisheries and Aquatic Sciences

Fisheries and Aquatic Sciences

- Address: Pukyong National University, 45 Yongso-ro, Nam-gu, Busan 48513, Korea
- Phone: +82-51-629-7363
- Email: kosfas@kosfas.or.kr
- Homepage : https://submission.e-fas.org/

Response to Reviewers

Dear Reviewers,

I would first thank you for commenting on our manuscript until this stage. We have changed the paper following the picture format of FAS. We also add short information to show the strength of the study. All revisions are given in Red. We hope that it could fulfill the requirements.

Wishes,

Silvester B. Pratasik
Corresponding author

Table 1. ANOVA on the effect of artificial bait light colors on the number of catches.

Source of Variance	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
Main Effects					
A: Trip	85653.0	9	9517.0	24.96	0.0000
B: Bait light color	$1.22351*10^{-6}$	3	407836.	1069.59	0.0000
A-B interactions	16791.1	27	621.892	1.63	0.0488
RESIDUAL	30504.0	80	381.3		
TOTAL	$1.35646*10^{-6}$	119			

Table 2. Multiple comparisons between treatment applications.

Bait light color comparisons	Difference	+/- Limits
BLUE – COM	171.167*	13.229
BLUE – GREEN	-109.067*	13.229
BLUE – RED-GREEN	54.8667*	13.229
COM – GREEN	-280.233*	13.229
COM – RED-GREEN	-116.3*	13.229
GREEN – RED-GREEN	163.933*	13.229

Note: * - significant difference

Behavioral r~~R~~esponse of p~~P~~urpleback f~~F~~lying s~~S~~quid *Stenoteuthis oualaniensis* (Mollusk; Cephalopod) to the f~~F~~lashlight a~~A~~rtificial b~~B~~ait c~~C~~olors

Lefrand Manoppo[1)], Silvester Benny~~.~~ Pratasik[2,*)], Effendi P. Sitanggang[1)], Lusia Manu[2)], Juliaan Cheyvert~~.~~ Watung[3)]

[1)] *Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, ~~Jl. Kampus Bahu Manado 95115,~~ North Sulawesi 95115, Indonesia~~;~~*

[2)] *Fisheries Resources Management, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, ~~Jl. Kampus Bahu Manado 95115,~~ North Sulawesi 95115, Indonesia~~;~~*

[3)] *Aquaculture, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, ~~Jl. Kampus Bahu Manado 95115,~~ North Sulawesi 95115, Indonesia~~.~~*

[*] **Corresponding author:** ~~S.B.~~ Silvester Benny Pratasik~~, spjong07@yahoo.com~~

Tel: +62-431-6868027, **E-mail:** spjong07@yahoo.com

메모 포함[GM61]: Author's information has been added referring to the submition system. Please check if the information is correct.

Abstract~~.~~

This study aimed to know the response of deep-sea squid *Stenoteuthis oualaniensis* to the light colors of the artificial bait. This experiment used the commercial artificial flashlight baits commonly sold in the fishing shop. The bait has several different light color combinations. The light colors were modified into several light colors by inactivating certain colors and used as treatments. The study is expected to be able to find flashlight bait's most effective color for squid fishing. ~~-~~We applied red-green, green, blue, and commercial bait lights in this study. Each treatment has 3 replications. The effect was expressed as the amount of squid caught. Data were analyzed by o~~O~~ne-w~~W~~ay analysis of variance~~ANOVA~~. Results showed a significant effect on

메모 포함[GM62]: Abbreviation is allowed only if the term is repeated in the text. This term has been replaced with its full-term, because the term appears only once in Abstract.

And for the same reason, some abbreviations have also been corrected. Please check all the modified terms in the text, carefully.

the number of squid catches. ~~–~~There was significantly different squid catches among the treatments. It indicates that this artificial flashlight bait could be developed to maximize squid catches. This finding can be used for the local fishermen's income and the squid fisheries development.

Keywords: C~~c~~ommercial jig, M~~m~~odification, E~~e~~ffect, C~~c~~atch~~.~~

Introduction

The exploitation of fisheries resources starts from a basic human need to obtain animal protein sources. Squid is one of the protein sources from the ocean, and nearly all body parts are edible. Since 1950, capture production of cephalopods has continued to grow (Doubleday et al., 2016; Hunsicker et al., 2010~~; Doubleday et al., 2016~~), with total commercial annual catches between 3.5 and 4.9 million tons in 2008–2017 (FAO, 2019), almost 4.6 times higher than that of the 1950s. Cephalopods on average support approximately 15% and 20% of marine fishery landings and landed values, respectively (~~Hunsicker et al., 2010; ~~FAO, 2019; Hunsicker et al., 2010). This group has unique life history characteristics, including rapid growth, short lifespan, and semelparous reproductive strategy, giving them both sensitivity and resilience to anthropogenic exploitation and oceanographic variability (Rodhouse et al., 2014). The species within the family Ommastrephidae support approximately 33.8% of the global cephalopod's landings (FAO, 2019). This group is recognized as voracious and adaptable predators of a broad range of prey including small crustaceans and fishes at early life stages and shift to micronekton, larger fishes, and cephalopods (including cannibalism) as they grow (Alegre et al., 2014; Nigmatullin et al., 2001~~;~~ ~~Alegre et al., 2014~~). Despite its economic importance, the offshore oceanic squid resources' exploitation rate is relatively low (Worms, 1983). ~~–~~The flying squids (Ommastrephidae; Oegopsid) cover about 65% of the world's commercial cephalopods (Brunetti, 1990; Roper et al., 1984~~; Brunetti, 1990~~) with a total of about 2.6 million in 1991 (FAO, 1993). The flying squids *Sthenoteuthis oualaniensis* (Lesson) and *Ommastrephes bratamii* are the oceanic species of this family that are distributed from the Indo-Pacific to the Indian Ocean. According to Voss (1973), the potential of the purpleback flying squids in the Central Eastern Pacific is at least 100,000

메모 포함[U3]: Citations have been rearranged alphabetically.

메모 포함[GM64]: No reference for this citation. Please add the paper in the Reference Section.

메모 포함[U5]: No reference for this citation. Please add the paper in the Reference Section.

metric tons. This species is caught commercially in the eastern and southern East China Sea, from Taiwan to Okinawa by hook and line with light at night (~~Yoshikawa 1978;~~ Okutani & Tung, 1978~~0~~; Tung, 1981; Yoshikawa, 1978~~,~~). The deep-sea squids caught by traditional fishermen of Manado Bay, North Sulawesi, in the Sulawesi Sea have been identified as a dwarf form of *S.~~thenoteuthis~~ oualaniensis* (Pratasik et al., 2022). These species are highly migratory and undertake diel vertical migrations of several hundred meters and seasonal migrations between the shelf and open ocean (Gilly et al., 2006; Stewart et al., 2013) so that they can act as important linkages between both neritic and oceanic food webs (Arkhipkin, 2013).

There are numerous studies on bait types to find the highest catch, from fish and shrimp flesh, live bait, and artificial bait. Fish and squids were observed to be attracted to squid jigging vessels due to the phototaxis (Rao,~~.~~ 1996). It is related to their behavior to avoid predators or enhance feeding efficiency (Solomon &~~and~~ Ahmed, 2016), and their response depends upon species, ontogenic development, light source characteristics, intensity, color, and wavelength (Mallawa et al., 1991). Therefore, fishermen catch squid using light that illuminates in water as well as jigs to attract the squids to aggregate and bite the jigs (Asokan &~~and~~ Krishnan, 2021). It relies on the artificial bait of shrimp-like siliconized jig fishing (Altinagac, 2006; Aydin & İlkyaz, 2021~~; Ulas & Aydin, 2011~~; Paighambari et al., 2012; Reza et al., 2019; Ulaş & Aydin, 2011~~; Aydin & İİlkyaz, 2021~~). Other studies on hand-line fishing are also done using different colors of shrimp-shaped jigs (Altinagac, 2006; Aydin & İlkyaz, 2021~~; Ulas & Aydin, 2011~~; Paighambari et al., 2012~~; Aydin & İİlkyaz, 2021~~; Ulaş & Aydin, 2011). Squid fishing in North Sulawesi is done by traditional fishermen using 5 to 7 M-boat and artificial bait either shrimp-like bait or other bait types (Fig. 1).

~~Fig. 1. Artificial bait. (a) shrimp-like bait and (b) flashlight jig: 1) flashlight; 2) one-meter line; 3) lead; 4) hook.~~

For deep-sea squid *S. oualaniensis* fishing, the fishermen use a mini-battery-supported flashlight artificial bait sold in the fishing stores. The flashlight artificial bait contains several different alternately blinking light colors to get the squid to bite. This study modifies the light colors to find the best modification of light color against the catches.

Materials and Methods

This study was carried out from June to July 2020. Traditional fishermen catch deep-sea squids *S. oualaniensis* in the Sulawesi Sea, North Sulawesi, at night (Fig. 2). The flashlight bait is facilitated with a mini-battery to be able to produce several different light colors to attract the squid. The flashlight was connected by a one-meter line to the hook working also as a lead. In fishing operations, the lead was coated with fish flesh as bait.

This experiment modified the standard commercial flashlight bait sold in the fishing shop to produce different light colors: r~~R~~ed-g~~G~~reen, b~~B~~lue, g~~G~~reen, and r~~R~~ed. These different light colors were used in 10 fishing trips. Twelve skillful fishermen were used in this experiment in which they were divided into 4 groups of 3 people in 4 separate traditional boats (7 m long) to operate each light color in the same fishing ground. The common commercial flashlight bait was also used as a control treatment. Each line used only one jig and all jig-fishing activities were carried out at the same time. The fishing line was lowered down to the depth range of 20–~~-~~25 M in the deep sea of Sulawesi Sea waters and jigged. This fishing depth is consistent with the dispersal range peak of *S. oualaniensis* (Jerep &~~and~~ Rop~~p~~er, 2010).

~~Fig. 2. Sampling site.~~

The use of the red-colored bait was eventually terminated because it was always cut off and lost. The experiment utilized only commercial bait, red-green bait, blue bait, and green bait as treatment with 3 replications represented by 3 local skillful fishermen for each bait light color. Data collections were squid catches. The catch data were analyzed with one-way analysis of variance ~~ANOVA~~ facilitated by statistical software for comparisons. ~~-~~The difference between treatments was then tested using Tukey's h~~H~~onestly s~~S~~ignificant d~~D~~ifference (HSD) procedure.

Results

This study caught a total of 30,687 squids *S. oualaniensis* during the fishing experiment in the Sulawesi Sea, North Sulawesi. Different light color applications highly significantly influenced the number of squid catches (*p*~~P~~ < 0.001). Analysis of v~~V~~ariance demonstrates that both trip and bait light color influence the squid catches (Table 1).

~~Table 1. ANOVA on the effect of artificial bait light colors on the number of catches.~~

Tukey's ~~Honestly Significant Difference (~~HSD~~)~~ test revealed that *S. oualaniensis* differently responded to the bait's light colors. All treatment applications gave a significantly different number of catches. ~~–~~Comparisons between treatments showed that all bait light color modifications gave a higher number of catches than the commercial one (Table 2).

~~Table 2. Multiple comparisons between treatment applications.~~

The significantly different squid catches are also indicated by the mean number of squid catches (Fig. 3). The green-lighted jig yielded the highest mean squid catches, 377.37 (39.46%), followed by blue light color, 268.3 (28.06%), then red-green, 213.43 (22.32%), and the lowest catches in the commercial artificial bait, 97.13 (10.16%) (Table 2 and Fig. 3). Multiple comparisons between treatment applications yielded 6 pairs of comparisons and indicated that all treatment flashlight jig colors yielded significantly different squid catches, in which single light colors also give the squid a higher response to taking the lure (Table 2).

~~Fig. 3. Mean catch of squid *S. oualaniensis* during the study.~~

Discussion

Jigging is an essential fishing method to exploit squids selectively and avoid overexploiting to conserve resources and energy (Asokan & Krishnan, 2021). It helps to adjust operational depth according to the concentration depth of squids. They are attracted to lights and fast-moving bait or any bait-like object. A typical jig consists of a shrimp or stalk-like body made of flexible plastic with one to three hooks or more sharp barbless steel hooks at the end. Other jigs are facilitated with the mini battery-supported light blinking.

Squids are known as color-blinded animals, but the degree of contrast is important for squid behavior to attack the jig (Flores et al., 1978). The use of a flashlight jig, in fact, gave a stronger degree of contrast in the water column at night fishing than the use of light above the water and could give a stronger stimulus to the squid to attack the fish flesh bait connected to blinking light. The flashlight jig also has a higher degree of contrast than the shrimp-like siliconized jig so that the squid more sensitively responds to the flashlight jig color in the water column. The flashlight acts as a squid-aggregating device, while the squid feeds on the fish's flesh, then caught by the hook. The flashlight jig could help the purpleback flying squid get the bait. All squids were hooked on the arms, indicating that the squids are feeding on the fish's flesh coated on the lead. On the other hand, cephalopods (squid, cuttlefish, and octopus) are well known as voracious predators of many preys, such as fish and crustaceans, or even have cannibalism behavior, so the contrast moving objects in the water column could indicate the presence of moving prey.

Furthermore, the present study revealed that the modified light colors of the artificial bait caught a higher number of deep-sea squid *S. oualaniensis* in the Sulawesi Sea than the common commercial artificial bait sold in the fishing store with a combination of several different colors. There was also a significantly different effect of all light color modifications on the squid catches with the highest catch in the green light. The low attacking preference of the purpleback flying squid to the multiple light colors could result from the squid's perception of the blinking multiple colors of the flashlight bait as the aposematic coloration of the prey, in which the animal shows the unpalatability or toxicity through warning coloration. This defense mechanism is widely discussed by Endler (1978), Mappes et al. (2005), Mochida et al. (2015), Stevens (2007), and Toledo & Haddad (2009). Aposematism is commonly found across the animal kingdom as a defense mechanism, and it could either be chemicals, such as toxins, harmful secretions, and venoms, or physical defense, such as spines, bites, and stings (Mappes et al., 2005).

메모 포함[U6]: No reference for this citation. Please add the paper in the Reference Section.

This finding is in agreement with Altinagac (2006) and Paighambari et al. (2012) that the green bait color is more efficient in squid jig fishing even though it does not have a significantly different effect from the use of red color in Turkish waters (Altinagac, 2006) and the blue color (Paighambari et al., 2012) on the catch rate of purpleback flying squids in Iranian waters of the Oman Sea. The sensitivity of fish and some of their food animals to blue and green colors is higher because of the long wavelengths that make them penetrate deeper into the water column (Solomon & Ahmed, 2016). The use of dark green jig color is also shown by the traditional fishermen, particularly in North Minahasa, North Sulawesi, as a potential bait color for demersal fish jig fishing (field obs.). Nevertheless, Ulaş &and Aydin (20112) found that the red jig is the most efficient in squid *Loligo vulgaris* Lamarck (1798) fishing on the Middle Eastern Coast of Aegean Sea, Turkey. All those findings were obtained using the shrimp-like siliconized bait. The local fishermen of North Sulawesi commonly use the shrimp-like siliconized jig to fish shallow water squids *Sepioteuthis lessoniana.* A different finding is shown by Arnupapboon et al. (2008) that the squid moves to white and blue more often than green, while the red color seemed not to attract the squids.

This fishing experiment reconfirms the previous finding concerning the most efficient bait color and shows that the use of single bait light color yielded higher catches than that of multiple colors (*p*P < 0.05). This study did not use the red light color as a treatment, since the red-lighted bait was always taken and cut off. Therefore, we had to use a wireline to the bait to know what causes the loss and found that the red light color was taken by the cutlassfish *Trichiurus* sp. The difference in squid's preference for jig color could result from environmental conditions with locality, such as predator-prey interactions that may alter the feeding behavior on-site and species. The presence of a higher level of the predator, such as cutlassfish *Trichiurus* sp., particularly in Sulawesi waters which is also attracted to the red-light jig has diminished the chance of the deep-sea squids *S. oualaniensis* to take the red jig or the squid *S. oualaniensis* is vulnerable to predation risk for feeding on the red-light jig.

According to Asokan &and Krishnan (2021), the efficiency of squid jigging is influenced by jig structure, jigging motion, light intensity, sea state, and sea surface temperature (Cabanellas-Reboredo et al., 2012; Roberts &and Sauer, 1994; Yu et al., 2015), wind speed, moon phase, and atmospheric pressure (Cabanellas-Reboredo et al., 2012), sea surface height anomaly (Yu et al., 2015), turbidity (Roberts &and Sauer, 1994), chlorophyll (Hurst et al., 2012), salinity (Yu et al., 2015), and large scales climate predictors, such as the Southern Oscillation Index (SOI) and the

메모 포함[U7]: Ulaş & Aydin (2012) changed to Ulaş & Aydin (2011) as per reference.

메모 포함[U8]: No reference for this citation.

North Atlantic Oscillation ~~(NAO)~~ (~~Roberts and Sauer, 1994;~~ Morales-Bojóorquez et al., 2001; Pierce et al., 2006; Roberts & Sauer, 1994),~~.~~ etc. These factors will influence the catches, recruitment, migration (Koopman et al., ~~(~~2018), and distribution of the squids. During squid jigging with lights, the quality of light (e.g., wavelength), the quantity of light (e.g., power), and the arrangement of fishing lights affect the squid's attraction. These factors create underwater irradiance levels and distribution influenced by the optical characteristics of seawater, and it influences squid behavior during fishing (Arakawa et al., 1998; Yamashita et al., 2012). According to Cabanellas-Reboredo et al. (2012), environmental variables, such as sea surface temperature, atmospheric pressure, and moon cycle can also influence squid catches. This experiment focused only on the effect of different jig light colors on the squid bites since the fishing was conducted in a single lunar cycle with different tide conditions. The jiggers took advantage of wind or current direction to position their boats in certain areas to avoid being drifted too far out of the mainland due to the use of the small boat (approximately 5–7 M long).

메모 포함[GM69]: Period (.) has been corrected to comma (,). Please check the if the contents is correct.

These findings showed that all light color modifications of the multiple flashlight-squid baits have contributed to the artificial squid flashlight bait development concerning the squid fishing effectivity. Light colors also influenced the feeding behavior of *S. oualaniensis*, and the single color gave the squid a higher response to getting the lure than the multiple colors. The highest squid catch was recorded in the green light color and the lowest was in the commercial artificial bait. Therefore, the present study has contributed to developing the mini-battery-supported artificial bait for effective exploitation to maximize offshore squid production and fisheries development so that the use of offshore squid resources could be increased. This information is also useful for traditional fishermen to increase their personal income through deep-sea squid fishing. Nevertheless, more studies on squid feeding behavior and other influencing environmental factors are needed for future squid population sustainability.

Competing ~~I~~interests

~~This article has no competing interests.~~No potential conflict of interest relevant to this article was reported.

메모 포함[GM610]: Item for Interest, Acknowledgements, Funding is set in *FAS* as follow. Please check if the contents of each item are correct.

Funding sources

Not applicable.

Acknowledgments

We would greatly appreciate the Rector of Sam Ratulangi University and the Dean of the Faculty of Fisheries and Marine Sciences who provided a small research grant. High appreciation is also addressed to Mr. Ponny Telleng who led the local fishermen of Manado Bay in fishing operations.

Availability of data and materials

Upon reasonable request, the datasets of this study can be available from the corresponding author.

Ethics approval and consent to participate

This article does not require IRB/IACUC approval because there are no human and animal participants.

ORCID

Lefrand Manoppo https://orcid.org/0000-0002-9154-4470

Silvester Benny Pratasik https://orcid.org/0000-0002-3765-509X

Effendi P. Sitanggang https://orcid.org/0000-0002-0256-2950

Lusia Manu https://orcid.org/0000-0001-6200-4451

Juliaan Cheyvert Watung https://orcid.org/0000-0002-8327-6488

References

Altinagac U. Effect of jigs color ton catching efficiency in the squid fishing in Turkey. Pakistan J. Biological Sci.ence 2006;9(15):2916-2918.

Arakawa H, Choi S, Arimoto T, Nakamura Y. Relationship between underwater irradiance and distribution of Japanese common squid under fishing lights of a squid jigging boat. Fisheries Science. 1998;64:553-557.

Arkhipkin AI. Squid as nutrient vectors linking Southwest Atlantic marine ecosystems. Deep. Sea Res. Part II Top. Stud. Oceanogr. 2013;95:7–-20. DOI: 10. 1016/j.dsr2.2012.07.003.

Arnupapboon S, Awaiwanont K, Monton Anongponyoskun M, Annanpongsuk Suphachai A, Bundit Chokesanguan B. Boosting the development of responsible squid light fishery:. aAssessment of squid feeding behavior. Southeast Asian Fisheries Development Center:. Fish for the Ppeople.: 2008; 6(1):p. 44-47. 2008

Asokan K, Krishnan AR. Techniques to squid jigging in India: aA review. J. Entomology and Zoology Stud.ies, 2021;9(3):415-422. DOI: https://doi.org/10.22271/j.ento.2021.v9.i3f.8743

Aydin C, İlkyaz AT. Catching performance and catching efficiency of siliconized baits in handline fishery. Journal of Agricultural Sciences (Tarim Bilimleri Dergisi). 2021;27(2): 219-230 DOI: 10.15832/ankutbd.606513 .

Brunetti NE. Description of *Rhynchoteuthion* larvae of *Illex argentinus* from the summer spawning subpopulation. J. Plankton Res. 1990;12:1045-1057.

Cabanellas-Reboredo M, Alóo´s J, Palmer M, Morales-Nin B. Environmental effects on recreational squid jigging fishery catches. ICES Journal of Marine Science. 2012;69(10): 1823–-1830. doi:10.1093/icesjms/fss159

Doubleday, ZA., Prowse TAA, Arkhipkin, A, Pierce GJ, Semmens J, Steer M., et al. Global proliferation of cephalopods. Curr. Biol. 2016;26:PR406387– 407. DOI: 10.1016/j.cub.2016.04.002. FAO (2019).

메모 포함[GM611]: References have been rearranged alphabetically.

Endler JA. A predator's view of animal color patterns. In: Hecht MK, Steere WC, Wallace B, editors. Evolutionary b~~B~~iology. New York, NY: Springer; ~~volume 11,~~ 1978. p. 319-~~3~~64.

Flores EE~~d~~C, Igarashi S, Mikai~~u~~mi T. Studies on squid behavior in relation to fishing: III. o~~O~~n the optomotor response of squid, *Todarodes pacificus* Steenstrup, to various colors. Bull~~.~~ ~~Fac.~~ Fish~~.~~ Hokkaido Univ. 1978;29~~(2)~~:131-~~1~~40.

Food and Agriculture Organization of the United Nations~~.~~ [FAO]. F~~-y~~~~Yearbook: f~~~~F~~ishery and a~~A~~quaculture s~~S~~tatistics 2017. Rome: FAO~~ood and Agriculture Organization of the United Nations~~; 2019.

Gilly WF, Markaida U, Baxter CH, Block BA, Boustany A, Zeidberg L, et al. Vertical and horizontal migrations by the jumbo squid *Dosidicus gigas* ~~were~~ revealed by electronic tagging. Mar~~.~~ Ecol~~.~~ Prog~~.~~ Ser. 2006;324:1~~—~~17. ~~DOI: 10. 3354/meps324001~~

Hunsicker ME, Essington TE, Watson R, Sumaila UR. The contribution of cephalopods to global marine fisheries: c~~C~~an we have our squid and eat them too? Fish Fish. 2010;11:421~~—~~~~4~~38. ~~DOI: 10.1111/j.1467-2979.2010.00369. x~~

Hurst RJ, Ballara SL, MacGibbon D, Triantafillos L. Fishery characteris~~z~~ation and standardis~~z~~ed CPUE analyses for arrow squid (*Nototodarus gouldi* and *N. sloanii*), 1989~~—~~90 to 2007~~—~~08, and potential management approaches for southern fisheries. Wellington: Ministry for Primary Industries~~New Zealand Fisheries Assessment Report~~; 2012. Report No.: ~~;~~2012/47. ~~303 p~~

Jerep P, Roper CFE. Cephalopods of the w~~W~~orld:~~.~~ a~~A~~n a~~A~~nnotated and i~~I~~llustrated c~~C~~atalogue of c~~C~~ephalopod s~~S~~pecies k~~K~~nown to date:~~, 2010;~~. v~~V~~ol~~.~~ 2. m~~M~~yopsid and o~~O~~egopsid squids. ~~FAO,~~ Rome: FAO; 2010.

Koopman M, Knuckey I, Cahill M. Improving the location and targeting of economically viable aggregations of squid available to the squid jigging method and the fleet's ability to catch squid. Canberra: Australian Fisheries Management Authority;~~.~~ 2018~~;223 p~~.

Mallawa A, Palo SM, Musbir. Study on bagan Rambo fisheries in Barru waters, Makassar Strait~~.~~ ~~Research Report Project~~. Makassar: Research Institute of Hasanuddin University~~,~~. ~~Makassar, (In Indonesian),~~; 1991~~, 40p~~. ~~Research Report Project.~~

메모 포함[GM612]: This paper is not verified online. If this paper is technical report, it should be added the Report Number. Please check the information again, and please provide as follows:

Technical material
Author. Title. Location: Publication; Year. Report No.: ??.

Dissertation
Author. Title [Ph.D. dissertation or M.S. thesis]. Location: Name of university; Year.

Mappes J, Marples N, Endler JA. The complex business of survival by aposematism. Trends~~RENDS in~~ Ecol~~ogy and~~ Evol~~ution~~.~~,~~ 2005;~~ ~~20~~(11)~~:~~ ~~598-603.

Marchesan M, Spoto M, Verginella L, Ferrero EA. Behavioural effects of artificial light on fish species of commercial interest. Fish Res. 2005;~~ ~~73:171-~~1~~85.

Mochida K, Zhang WY, Toda M. The function of body coloration of the hai coral snake *Sinomicrurus japonicus boettgeri*. Zool~~ogical~~ Stud.~~ies,~~ 2015;~~,~~54:33~~. 6p~~.

Morales-Bo~~r~~jó~~o~~rquez E, Cisneros-Mata~~,~~ MA, Nevá~~a~~rez-Martinez MO, Herná~~a~~ndez-Herrera A. Review of stock assessment and fishery biology of *Dosidicus gigas* in the Gulf of California, Mexico. Fish~~eries~~ Res.~~earch~~ 2001;54:~~ ~~83-94.

Nigmatullin CM, Nesis KN, Arkhipkin AI. A review of the biology of the jumbo squid *Dosidicus gigas* (Cephalopoda: Ommastrephidae). Fish~~.~~ Res. 2001;54:9–~~-~~19.~~ DOI: 10.1016/S0165-7836(01)00371-X~~

Okutani T, Tung IH. Reviews of biology of commercially important squids in Japanese and adjacent waters:~~.,~~ I. *Symplectoteuthis oualaniensis* (l~~L~~esson). Veliger. 19~~8~~78;21~~(1)~~:~~ ~~87-94.

Paighambari SY, Daliri M, Memarzade M. The effects of jig color and depth variation on catch rates of purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1830) in Iranian w~~W~~aters of the Oman Sea. Casp J Appl Sci Res~~World Journal of Fish and Marine Sciences~~. 2012;14~~(5)~~:~~ ~~1-5~~458-461~~. ~~DOI: 10.5829/idosi.wjfms.2012.04.05.6415~~

Pierce GJ, ~~Begoña ~~Santos MB, MacLeod CD, Wang J, Valavanis V, Zuur AF. Modelling environmental influences on squid life history, distribution, and abundance. In: Proceedings of the GLOBEC-CLIOTOP WG3 Workshop; 2006; Hawaii, HI, USA~~USA~~.~~The role of squid in open ocean ecosystems, 16-17 November 2006., Hawaii, USA.~~

Pratasik SB, Lalamentik LTX, Manoppo L, Budiman J. Deep sea squid in Sulawesi s~~S~~ea, North Sulawesi p~~P~~rovince, Indonesia. Biodiversitas. 2022;23~~(4)~~:1774-~~177~~9.~~ DOI: 10.13057/biodiv/d230408~~

메모 포함[GM613]: No citation for this reference. Please cite this paper in the text.

메모 포함[GM614]: There is no issue number 5 in the *World Journal of Fish and Marine Sceiences*.
Source: https://idosi.org/wjfms/online.htm

So the journal information has been corrected by referring to the following source:
https://journals.indexcopernicus.com/search/article?articleId=300255

Rao KS. Cephalopod fishing. In: Proceedings of the Aquaculture Foundation of India & The Fisheries Technocrats Forum~~Seminar on Fisheries – A Multibillion Dollar Industry~~; 1995;~~,~~ Chennai, India~~Madras, Aug 17-19, 1995 Aquaculture Foundation of India & The Fisheries Technocrats Forum;~~. ~~1996;~~: ~~Madras~~12-~~20~~.

Reza FA, Umroh U, Utami E. The effect of bait types on squid capture *Loligo* sp.~~ capture~~ in Tuing waters~~,~~ of Bangka Regency. J~~.~~ Aquatropica Asia. 2019;~~ 4 (1)~~:20-~~2~~5. ~~[In Indonesian].~~

Roberts MJ, Sauer WHH. Environment: t~~T~~he key to understanding the South African chokka squid (*Loligo vulgaris reynaudii*~~o~~) life cycle and fishery? Antarct~~ic~~ Sci~~ence~~. 1994;~~ 6(2)~~: 249-~~2~~58.

Rodhouse PGK, Pierce GJ, Nichols OC, Sauer WHH, Arkhipkin AI, Laptikhovsky VV, et al. Environmental effects on cephalopod population dynamics: i~~I~~mplications for management of fisheries. Adv~~.~~ Mar~~.~~ Biol. 2014;67~~:,~~ 99~~–~~233. ~~DOI: 10.1016/b978-0-12-800287-2.00002-0~~

Roper C~~E~~F~~E~~, Sweeney MJ, Nauen C. FAO species catalogue: vol. 3. c~~C~~ephalopods of the w~~W~~orld~~:, Vol.3,~~ a~~A~~n annotated and illustrated catalogue of species of interest to fisheries. Rome~~, Italy~~: FAO~~ Fisheries Synopsis;~~ 1984.~~; 125, Rome, 277pp.~~

Solomon OO, Ahmed OO. Fishing with light: e~~E~~cological consequences for coastal habitats. Int~~ernational~~ J~~ournal of~~ Fish~~eries and~~ Aquat~~ic~~ Stud~~ies~~ 2016;~~ 4(2)~~: 474-~~4~~83.

Stewart JS, Gilly WF, Field JC, Payne JC. Onshore–~~-~~offshore movement of jumbo squid (*Dosidicus gigas*) on the continental shelf. Deep~~.~~ Sea Res~~.~~ II Top~~.~~ Stud~~.~~ Oceanogr. 2013;95:~~ ~~193–~~ 19~~6. ~~DOI: 10.1016/j.dsr2.2012. 08.019~~

Toledo LF, Haddad CFB. Colors and some morphological traits as defensive mechanisms in a~~A~~nurans. Int~~.~~ J~~.~~ Zool.~~ogy,~~ 2009;~~ 2009:~~910892~~12p~~.

Tung IH. On the fishery and biology of the squid, *Ommastrephes bartramii*, in the northwest Pacific Ocean. Rep~~.~~ Inst ~~.~~Fish ~~.~~Biol~~.,~~ Taipei~~.,~~ 1981;3~~(4)~~:~~ ~~12-37.

Ulaş A, Aydin I. The effects of jig colors~~s~~ and lunar bright~~ness~~ on coastal squid jigging. Afr~~ican~~ J~~ournal of~~ Biotechnol~~ogy~~. 2011;~~ ~~10~~(9)~~:1721-~~172~~6. ~~DOI: 10.5897/AJB10.1775~~

메모 포함[GM615]: Forum information cannot be confirmed on Internet. Please check if the information is crrect.

Voss~~,~~ G~~.~~ L~~., 1973~~. Cephalopod resources of the world. ~~FAO Fisheries. Circular No. 149.~~ Rome: ~~Food and Agriculture Organization of the United Nations~~FAO;~~.~~ 1973~~; 149: 75p~~.

Worms~~,~~ J. World fisheries for cephalopods: a~~A~~ synoptic overview. In: ~~J. F.~~ Caddy JF, editor. ~~1983 (Ed.)~~ Advances in a~~A~~ssessment of w~~W~~orld c~~C~~ephalopod r~~R~~esources. ~~FAO Tech. FAO.~~ Rome: FAO;~~.~~ 19~~90~~83~~; 231:~~. p. 1-20.

Yamashita Y, Matsushita Y, Azuno T. Catch performance of coastal squid jigging boats using LED panels in combination with metal halide lamps. Fish~~eries~~ Res~~earch~~. 2012;113:182-~~18~~9.

Yoshikawa N. Fisheries in Japan: ~~S~~squid and c~~C~~uttlefish. Tokyo:~~,~~ Japan Marine Products Photo Materials Association;~~.~~ 1978~~; 161p~~.

Yu W, Chen X, Yi Q, Chen Y, Zhang Y. Variability of suitable habitat of western winter-spring cohort for neon flying squid in the n~~N~~orthwest Pacific under anomalous environments. PLO~~o~~S ONE. 2015;10~~(4)~~: e0122997. ~~doi:10.1371/journal. pone.0122997~~

메모 포함[GM616]: This paper cannot be confirmed on Internet. Please check if the title is correct.

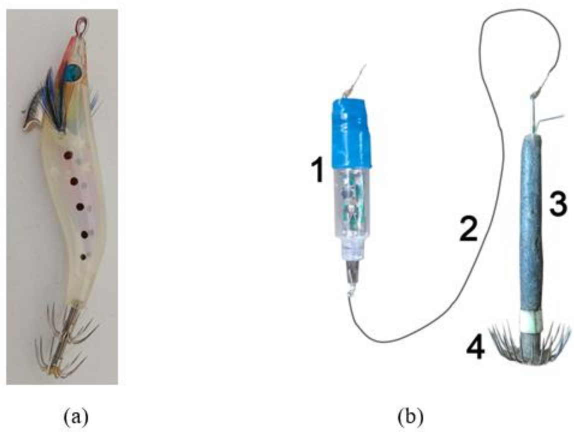


Fig. 1. Artificial bait. (a) Sshrimp-like bait and (b) flashlight jig.

1) Flashlight; 2) one-meter line; 3) lead; 4) hook.

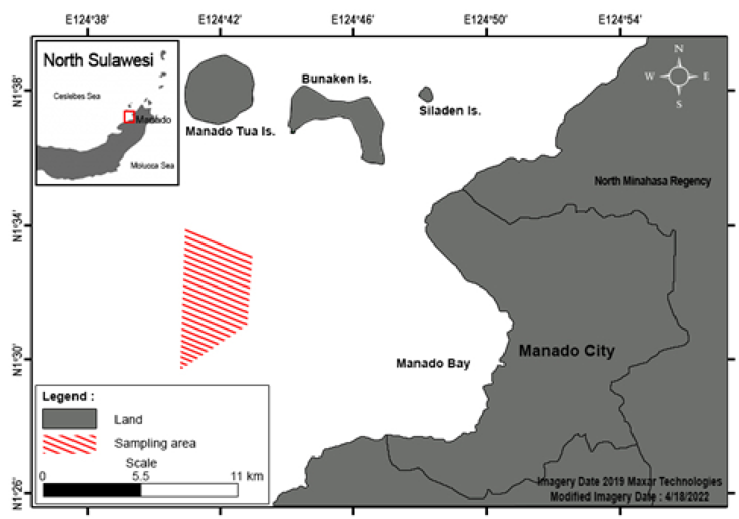


Fig. 2. Sampling site.

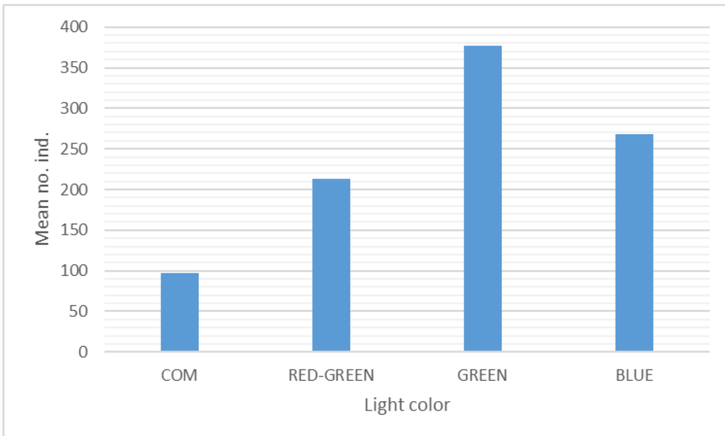


Fig. 3. Mean catch of squid *Sthenoteuthis~~.~~ oualaniensis* during the study.

Table 1. Analysis of variance~~NOVA~~ on the effect of artificial bait light colors on the number of catches~~.~~

Source of v~~V~~ariance	Sum of s~~S~~quares	*Df*	Mean s~~S~~quare	*F*-r~~R~~atio	~~P~~*p*-v~~V~~alue
Main e~~E~~ffects					
A: Trip	85,653.0	9	9,517.0	24.96	0.0000
B: Bait light color	1.22351 × ~~*~~10^{-6}	3	407,836~~.~~	1,069.59	0.0000
A-B interactions	16,791.1	27	621.892	1.63	0.0488
Residual	30,504.0	80	381.3		
Total	1.35646 × ~~*~~10^{-6}	119			

Table 2. Multiple comparisons between treatment applications.

Bait light color comparisons	Difference	+/– Limits
BLUE–COM	171.167*	13.229
BLUE–GREEN	–109.067*	13.229
BLUE–RED-GREEN	54.8667*	13.229
COM–GREEN	–280.233*	13.229
COM–RED-GREEN	–116.3*	13.229
GREEN–RED-GREEN	163.933*	13.229

Note: *Significant difference.

메모 포함[g517]: Please write the probability
Ex) *Significant difference (p<0.05)

RESEARCH ARTICLE
eISSN 2234-1757
Fish Aquat Sci. 2023;26(5):1-000
https://doi.org/10.47853/FAS.2023.e28
FAS Fisheries and Aquatic Sciences

Behavioral response of purple back flying squid *Sthenoteuthis oualaniensis* (Mollusk; Cephalopod) to the flashlight artificial bait colors

Lefrand Manoppo[1], Silvester Benny Pratasik[2,*], Effendi P. Sitanggang[1], Lusia Manu[2], Juliaan Cheyvert Watung[3]

[1]*Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, North Sulawesi 95115, Indonesia*
[2]*Fisheries Resources Management, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, North Sulawesi 95115, Indonesia*
[3]*Aquaculture, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, North Sulawesi 95115, Indonesia*

Abstract
This study aimed to know the response of deep-sea squid *Sthenoteuthis oualaniensis* to the light colors of the artificial bait. This experiment used the commercial artificial flashlight baits commonly sold in the fishing shop. The bait has several different light color combinations. The light colors were modified into several light colors by inactivating certain colors and used as treatments. The study is expected to be able to find flashlight bait's most effective color for squid fishing. We applied red-green, green, blue, and commercial bait lights in this study. Each treatment has 3 replications. The effect was expressed as the amount of squid caught. Data were analyzed by one-way analysis of variance. Results showed a significant effect on the number of squid catches. There was significantly different squid catches among the treatments. It indicates that this artificial flashlight bait could be developed to maximize squid catches. This finding can be used for the local fishermen's income and the squid fisheries development.
Keywords: Commercial jig, Modification, Effect, Catch

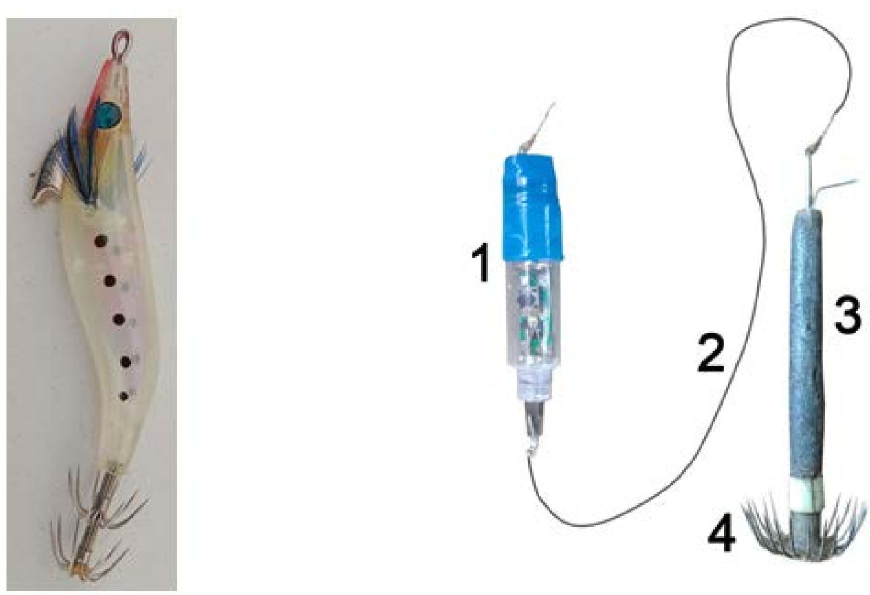
Introduction

The exploitation of fisheries resources starts from a basic human need to obtain animal protein sources. Squid is one of the protein sources from the ocean, and nearly all body parts are edible. Since 1950, capture production of cephalopods has continued to grow (Doubleday et al., 2016; Hunsicker et al., 2010), with total commercial annual catches between 3.5 and 4.9 million tons in 2008–2017 (FAO, 2019), almost 4.6 times higher than that of the 1950s. Cephalopods on average support approximately 15% and 20% of marine fishery landings and landed values, respectively (FAO, 2019; Hunsicker et al., 2010). This group has unique life history characteristics, including rapid growth, short life span, and semelparous reproductive strategy, giving them both sensitivity and resilience to anthropogenic exploitation and oceanographic variability (Rodhouse et al., 2014). The species within the family Ommastrephidae support approximately 33.8% of the global cephalopod's landings (FAO, 2019). This group is recognized

Received: Aug 15, 2022 Revised: Jan 24, 2023 Accepted: Jan 26, 2023
*Corresponding author: Silvester Benny Pratasik
Fisheries Resources Management, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, North Sulawesi 95115, Indonesia
Tel: +62-431-6868027, E-mail: spjong07@yahoo.com

as voracious and adaptable predators of a broad range of prey including small crustaceans and fishes at early life stages and shift to micronekton, larger fishes, and cephalopods (including cannibalism) as they grow (Alegre et al., 2014; Nigmatullin et al., 2001). Despite its economic importance, the offshore oceanic squid resources' exploitation rate is relatively low (Worms, 1983). The flying squids (Ommastrephidae; Oegopsid) cover about 65% of the world's commercial cephalopods (Brunetti, 1990; Roper et al., 1984) with a total of about 2.6 million in 1991 (FAO, 1993). The flying squids *Sthenoteuthis oualaniensis* (Lesson) and *Ommastrephes bratamii* are the oceanic species of this family that are distributed from the Indo-Pacific to the Indian Ocean. According to Voss (1973), the potential of the purpleback flying squids in the Central Eastern Pacific is at least 100,000 metric tons. This species is caught commercially in the eastern and southern East China Sea, from Taiwan to Okinawa by hook and line with light at night (Okutani & Tung, 1978; Tung, 1981; Yoshikawa, 1978). The deep-sea squids caught by traditional fishermen of Manado Bay, North Sulawesi, in the Sulawesi Sea have been identified as a dwarf form of *S. oualaniensis* (Pratasik et al., 2022). These species are highly migratory and undertake diel vertical migrations of several hundred meters and seasonal migrations between the shelf and open ocean (Gilly et al., 2006; Stewart et al., 2013) so that they can act as important linkages between both neritic and oceanic food webs (Arkhipkin, 2013).

There are numerous studies on bait types to find the highest catch, from fish and shrimp flesh, live bait, and artificial bait. Fish and squids were observed to be attracted to squid jigging vessels due to the phototaxis (Rao, 1996). It is related to their behavior to avoid predators or enhance feeding efficiency (Solomon & Ahmed, 2016), and their response depends upon species, ontogenic development, light source characteristics, intensity, color, and wavelength (Mallawa et al., 1991). Therefore, fishermen catch squid using light that illuminates in water as well as jigs to attract the squids to aggregate and bite the jigs (Asokan & Krishnan, 2021). It relies on the artificial bait of shrimp-like siliconized jig fishing (Altinagac, 2006; Aydin & İlkyaz, 2021; Paighambari et al., 2012; Reza et al., 2019; Ulaş & Aydin, 2011). Other studies on hand-line fishing are also done using different colors of shrimp-shaped jigs (Altinagac, 2006; Aydin & İlkyaz, 2021; Paighambari et al., 2012; Ulaş & Aydin, 2011). Squid fishing in North Sulawesi is done by traditional fishermen using 5 to 7 M-boat and artificial bait either shrimp-like bait or other Bait types (Fig. 1).



(a) (b)

Fig. 1. Artificial bait. (a) Shrimp-like bait and (b) flashlight jig. 1) Flashlight; 2) one-meter line; 3) lead; 4) hook.

https://doi.org/10.47853/FAS.2023.e28

Fordeep-seasquid*S.oualaniensis*fishing,thefishermen useamini-battery-supportedflashlightartificialbaitsoldin thefishingstores.Theflashlightartificialbaitcontainsseveral differentalternatelyblinkinglightcolorstogetthesquidtobite. This studymodifiesthelightcolorstofindthe bestmodification oflightcoloragainstthecatches.

MaterialsandMethods

Thisstudy wascarriedoutfromJunetoJuly2020.Traditional fishermencatchdeep-seasquids*S.oualaniensis*intheSulawesi Sea,NorthSulawesi,atnight(Fig.2).Theflashlightbaitis facilitatedwithamini-batterytobeabletoproduceseveral different lightcolorstoattractthesquid.Theflashlightwas connectedbyaone-meterlinetothehookworkingalsoasalead. Infishingoperations,theleadwascoatedwithfishfleshasbait.

Thisexperiment modified thestandardcommercial flashlightbaitsoldinthefishingshoptoproducedifferentlight colors:red-green,blue,green,and red.Thesedifferentlightcolors wereusedin10fishingtrips.Twelveskillfulfishermenwereused in thisexperimentin whichtheyweredividedinto 4groupsof3peoplein 4separatetraditionalboats(7mlong)to operateeach lightcolorinthesamefishingground.Thecommoncommercial flashlightbaitwasalsousedasacontroltreatment.Eachline used onlyone jigandalljig-fishingactivitieswerecarriedoutat thesametime.Thefishinglinewasloweredown tothedepth rangeof20–25MinthedeepseaofSulawesiSeawatersand jigged.Thisfishingdepthisconsistent withthedispersalrange peakof*S.oualaniensis*(Jerep&Roper,2010).

Theuseofthered-coloredbaitwaseventuallyterminated becauseitwasalwayscutoffandlost.Theexperiment utilized onlycommercialbait,red-greenbait,bluebait,andgreen bait astreatmentwith 3replicationsrepresentedby3localskillful fishermenforeachbait lightcolor.Data collectionsweresquid catches.Thecatchdatawereanalyzedwithone-wayanalysisof variancefacilitatedbystatisticalsoftwarefor comparisons.The differencebetweentreatmentswasthentestedusingTukey's honestly significantdifference(HSD)procedure.

Results

Thisstudycaughtatotalof30,687squids*S.oualaniensis*during thefishingexperimentintheSulawesiSea,NorthSulawesi. Differentlightcolorapplicationshighlysignificantlyinfluenced

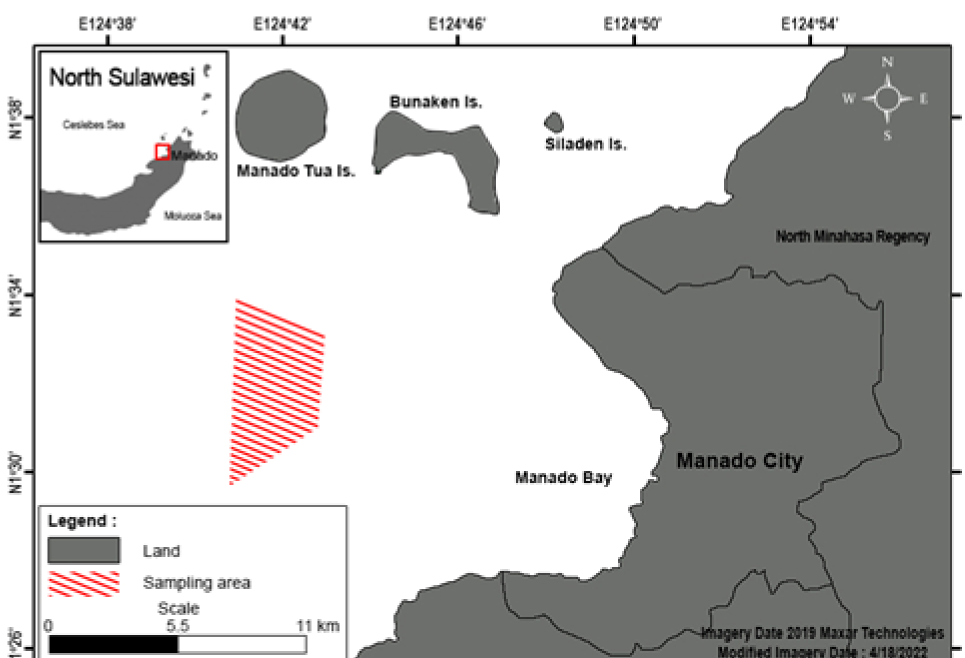


Fig.2.Samplingsite.

Thenumberofsquidcatches(p<0.001).Analysisofvariance demonstratesthatbothtripandbaitlightcolorinfluencethe squidcatches(Table1).

Tukey'sHSDtestrevealedthat*S.oualaniensis*differently respondedtothebait'slightcolors.Alltreatmentapplications gaveasignificantlydifferentnumberofcatches.Comparisons betweentreatmentsshowedthat allbaitlightcolormodifications gaveahighernumberofcatchesthanthecommercial one (Table2).

Thesignificantlydifferentsquidcatchesarealsoindicated bythemeannumberofsquidcatches(Fig.3).Thegreen-lighted jigyieldedthehighest meansquidcatches,377.37(39.46%), followedbybluelight color,268.3(28.06%),thenred-green, 213.43(22.32%),andthelowestcatchesinthecommercial artificialbait,97.13(10.16%)(Table2andFig.3).Multiple comparisonsbetweentreatmentapplicationsyielded6 pairsof comparisonsandindicatedthatalltreatmentflashlightjigcolors yieldedsignificantlydifferentsquidcatches,inwhichsinglelight coloralsogivethesquidahigherresponse totakingthelure (Table2).

Discussion

Jiggingisanessentialfishingmethodtoexploitsquidsselectively andavoidover-exploitationtoconserveresources andenergy(Asokan&Krishnan,2021).Ithelpstoadjustoperati onal depthaccordingtotheconcentrationdepthofsquids.Theyare attractedto lightsandfast-movingbait oranybait-likeobject.A typicaljigconsistsofashrimporstalk-likebodymadeofflexible plasticwithonetothreehooksormoresharpbarblesssteel hooksattheend.Otherjigs arefacilitatedwiththeminibattery-supportedlightblinking.

Squidsareknownascolor-blindedanimals,butthedegree of contrastisimportantforsquidbehavior toattackthejig (Floresetal.,1978).Theuse ofaflashlightjig,infact,gavea strongerdegreeofcontrastinthewatercolumnatnightfishing thantheuseoflightabovethewaterandcouldgiveastronger stimulustothesquidtoattackthefishfleshbaitconnected toblinkinglight.Theflashlightjigalsohasahigherdegreeof contrastthantheshrimp-likesiliconizedjigso thatthesquid moresensitivelyrespondstotheflashlightjigcolorinthewater column.Theflashlightactsasasquid-aggregatingdevice,while thesquidfeedsonthefish'sflesh,thencaughtbythehook.The flashlightjigcouldhelpthepurplebackflyingsquidgetthebait. Allsquidswerehooked onthearms,indicatingthatthesquids arefeedingonthefish'sfleshcoated onthelead.Ontheother hand,cephalopods (squid,cuttlefish,andoctopus)arewell knownas voraciouspredatorsofmanypreys,suchasfishand crustaceans,orevenhavecannibalismbehavior,sothecontrast

Table1.Analysisofvarianceontheeffectofartificialbaitlightcolorsonthenumberofcatches

Source of variance	Sum of squares	*Df*	Mean square	*F*-ratio	*p*-value
Main effects					
A:Trip	85,653.00	9	9,517.00	24.96	0
B: Bait light color	$1.22351\times10_{-6}$	3	407,83	1,069.59	0
A-B inter actions	16,791.10	27	621.89	1.63	0.0488
Residual	30,504.00	80	381		
Total	$1.35646\times10_{-6}$	119			

Table2.Multiplecomparisonsbetweentreatmentapplications

Bait light color comparisons	Difference	+/–Limits
BLUE–COM	171.167*	13.229
BLUE–GREEN	–109.067*	13.229
BLUE–RED-GREEN	54.8667*	13.229
COM–GREEN	–280.233*	13.229
COM–RED-GREEN	–116.3*	13.229
GREEN–RED-GREEN	163.933*	13.229

*Significantdifference.

https://doi.org/10.47853/FAS.2023.e28

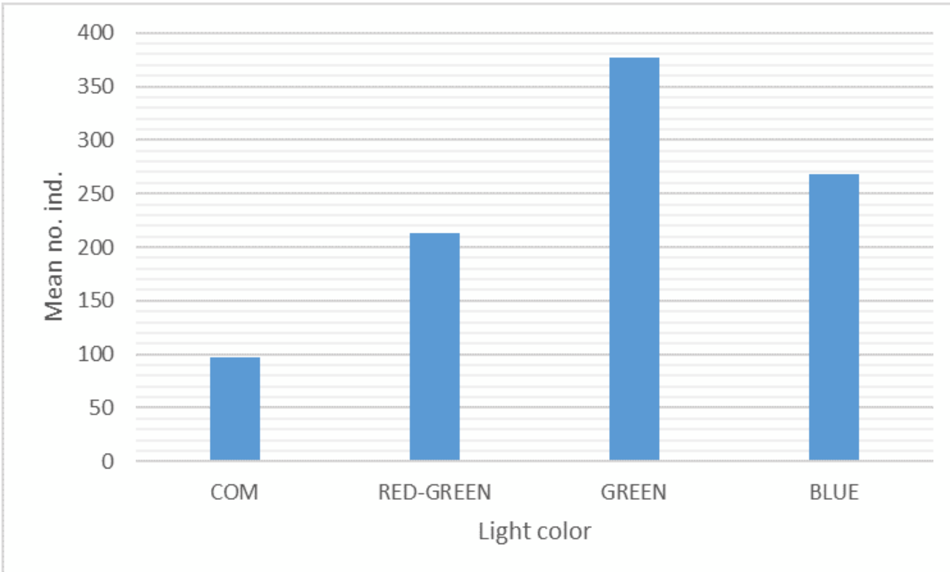


Fig.3.MeancatchofsquidSthenoteuthisoualaniensisduringthestudy.

movingobjectsinthewatercolumn couldindicatethepresence ofmovingprey.

Furthermore,thepresentstudyrevealedthatthemodified lightcolors oftheartificialbaitcaughtahighernumberof deep-seasquid*S.oualaniensis*intheSulawesiSeathanthe commoncommercialartificialbaitsoldinthefishingstore witha combinationofseveraldifferentcolors.Therewasalsoa significantlydifferenteffectofalllightcolormodificationson thesquid catcheswiththehighestcatch inthegreenlight.The lowattackingpreferenceofthepurplebackflyingsquidtothe multiplelightcolorscouldresultfromthesquid'sperception oftheblinkingmultiplecolorsoftheflashlightbaitasthe aposematiccolorationoftheprey,inwhichtheanimalshows theunpalatabilityortoxicitythroughwarning coloration.This defensemechanismiswidelydiscussedbyEndler(1978),Kang et al. (2015), Mappesetal.(2005),Mochidaetal.(2015),andToledo &Haddad(2009).Aposematismiscommonlyfoundacrossthe animal kingdomasadefensemechanism,andit couldeither be chemicals,suchas toxins,harmfulsecretions,andvenoms,or physicaldefense,suchasspines,bites,andstings(Mappeset al., 2005).

ThisfindingisinagreementwithAltinagac(2006)and Paighambarietal.(2012)thatthegreenbaitcolorismore efficientinsquidjigfishingeventhoughitdoesnothave a significantlydifferenteffectfromtheuseofredcolorinTurkish Waters(Altinagac,2006)andthebluecolor(Paighambarietal., 2012)onthecatch rateofpurplebackflyingsquidsinIranian waters oftheOmanSea.Thesensitivityoffishandsomeoftheir foodanimals toblue andgreencolorsishigherbecauseofthe long wavelengthsthatmakethempenetratedeeperintothe watercolumn(Solomon&Ahmed,2016).Theuseofdarkgreen jigcolorisalsoshownbythetraditionalfishermen,particularly inNorthMinahasa,NorthSulawesi,asa potential baitcolorfor demersalfishjigfishing(fieldobs.).Nevertheless,Ulaş&Aydin (2011)foundthattheredjigisthemostefficientinsquid*Loligovulgaris* fishingontheMiddleEasternCoast ofAegeanSea,Turkey.Allthose findingswereobtainedusing theshrimp-likesiliconizedbait. ThelocalfishermenofNorth Sulawesicommonly use theshrimp-like siliconizedjigtofish shallowwatersquids*Sepioteuthislessoniana.*Adifferentfinding is shownbyArnupapboonetal.(2008)thatthesquidmoves towhite andblue moreoftenthangreen,whiletheredcolor seemednottoattractthesquids.

Thisfishingexperimentreconfirmsthepreviousfinding concerningthemostefficientbaitcolorandshowsthatthe use ofsinglebait lightcoloryieldedhighercatchesthanthatof multiplecolors(p<0.05).Thisstudy didnotusetheredlight colorasatreatment,sincethered-lightedbaitwasalwaystaken andcutoff.Therefore,wehadtouse awirelinetothebaitto know whatcausesthelossandfoundthattheredlightcolor wastakenby thecutlassfish*Trichiurus*sp.Thedifferencein squid'spreferenceforjigcolorcouldresult fromenvironmental conditionswithlocality,suchaspredator-preyinteractionsthat mayalterthe feedingbehavioron-siteandspecies.Thepresence ofahigherlevelofthepredator,suchascutlassfish*Trichiurus*sp.,part icularlyinSulawesiwaterswhichisalsoattractedtothe red-lightjighasdiminishedthechanceofthedeep-seasquids *S.oualaniensis*totaketheredjigorthesquid*S.oualaniensis*is vulnerabletopredationriskforfeedingonthered-lightjig.

AccordingtoAsokan&Krishnan(2021),theefficiencyof squidjiggingisinfluencedbyjigstructure,jiggingmotion,light intensity,seastate, andseasurfacetemperature(Cabanellas-Reboredoetal.,2012;Roberts&Sauer,1994;Yuetal.,2015), windspeed,moon phase,andatmosphericpressure(Cabanellas-Reboredoetal.,2012),seasurfaceheightanomaly(Yuetal., 2015),turbidity(Roberts&Sauer,1994),chlorophyll(Hurst etal.,2012),salinity(Yuetal.,2015),andlargescalesclimate predictors,suchastheSouthernOscillationIndexandtheNorth AtlanticOscillation(Morales-Bojórquezetal.,2001;Pierceetal., 2006;Roberts&Sauer,1994),etc.Thesefactorswillinfluence thecatches,recruitment,migration(Koopmanetal.,2018), anddistributionofthesquids.Duringsquidjiggingwithlights, thequalityoflight(e.g.wavelength),thequantityoflight(e.g., power),andthearrangementoffishinglightsaffectthesquid's attraction.Thesefactorscreateunderwaterirradiance levelsand distributioninfluencedbytheopticalcharacteristicsofseawater, anditinfluencessquidbehavior duringfishing(Arakawaet al.,1998;Yamashitaetal.,2012).AccordingtoCabanellas-Reboredoetal.(2012),environmentalvariables,suchas sea surfacetemperature,atmosphericpressure,andmooncyclecana lsoinfluencesquid catches.Thisexperimentfocusedonly ontheeffectofdifferentjiglightcolorsonthesquidbitessince thefishingwasconductedinasinglelunarcyclewith different tideconditions.Thejiggerstookadvantageofwind orcurrent directiontopositiontheirboats incertainareastoavoidbeing driftedtoofaroutofthemainlandduetotheuseofthesmall boat(approximately5–7Mlong).

Thesefindingsshowedthatalllight colormodifications of themultipleflashlight-squidbaits havecontributedtothe artificialsquidflashlightbaitdevelopmentconcerningthe squidfishingeffectivity.Lightcolorsalsoinfluencedthefeeding behaviorof*S.oualaniensis*,andthesinglecolorgavethesquida higherresponsetogettingthelurethanthemultiplecolors.The highestsquidcatchwasrecordedinthegreenlightcolorand the lowestwasinthecommercialartificialbait.Therefore,thepresent studyhas contributedtodevelopingthemini-battery-supported artificialbaitforeffectiveexploitation tomaximizeoffshoresquid productionandfisheriesdevelopmentsothattheuseofoffshore squidresourcescouldbeincreased.Thisinformationisalso usefulfortraditionalfishermentoincreasetheirpersonalincome throughdeep-seasquidfishing.Nevertheless,morestudieson squidfeedingbehavior andotherinfluencingenvironmental factorsareneededforfuturesquidpopulationsustainability.

Competinginterests

Nopotentialconflict ofinterestrelevanttothisarticlewasreported.

Fundingsources

Notapplicable.

Acknowledgements

WewouldgreatlyappreciatetheRectorof SamRatulangiUniversityandtheDeanoftheFacultyofFisheriesand MarineScienceswhoprovidedasmallresearchgrant.Highapprecia tion isalsoaddressedtoMr.PonnyTellengwholedthelocalfisher-men ofManadoBayinfishingoperations.

Availabilityofdataandmaterials

Uponreasonablerequest,thedatasetsofthisstudycanbeavailablefro mthecorrespondingauthor.

Ethicsapprovalandconsenttoparticipate

ThisarticledoesnotrequireIRB/IACUCapprovalbecause therearenohumanand animalparticipants.

ORCID

LefrandManoppohttps://orcid.org/0000-0002-9154-4470

SilvesterBennyPratasik https://orcid.org/0000-0002-3765-509X

EffendiP.Sitangganghttps://orcid.org/0000-0002-0256-2950

LusiaManu https://orcid.org/0000-0001-6200-4451

JuliaanCheyvertWatung https://orcid.org/0000-0002-8327-6488

References

Alegre A, Ménard F, Tafur R, Espinoza P, Argüelles J, Maehara V, Flores O, Simier M, Bertrand A. 2014. Comprehensive model of jumbo squid Dosidicusgigas trophic ecology in the northern Humboldt 1779 current system. Plos One 9: e0085919. DOI: 10.1371/journal. pone. 0085919

AltinagacU.Effectofjigscolortocatchingefficiencyinthesquidfis hinginTurkey.PakJBiolSci.2006;9:2916-8.

ArakawaH,ChoiS,ArimotoT,NakamuraY.Relationshipbe-

https://doi.org/10.47853/FAS.2023.e28

tweenunderwaterirradianceanddistributionofJapanesecom monsquidunderfishinglightsofasquidjiggingboat. FishSci.1998;64:553-7.

ArkhipkinAI.SquidasnutrientvectorslinkingSouthwestAt-lanticmarineecosystems.DeepSeaResIITopStudOcean-ogr.2013;95:7-20.

ArnupapboonS,AwaiwanontK,MontonA,SuphachaiA,Bun-ditC.Boostingthedevelopmentofresponsiblesquidlightfisher y:assessmentofsquidfeedingbehavior.FishPeople. 2008;6:44-7.

AsokanK,KrishnanAR.TechniquestosquidjigginginIndia:areview .JEntomolZoolStud.2021;9:415-22.

AydinC, İlkyazAT.Catchingperformanceandcatchingeffi-ciencyofsiliconizedbaitsinhandlinefishery.JAgricSci. 2021;27:219-30.

BrunettiNE.Descriptionof*Rhynchoteuthion*larvaeof*Illexargentinus*fromthesummerspawningsubpopulation.JPlankton Res.1990;12:1045-57.

Cabanellas-ReboredoM,AlósJ,PalmerM,Morales-NinB. Environmentaleffectsonrecreationalsquidjiggingfishery catches.ICES JMarSci.2012;69:1823-30.

DoubledayZA,ProwseTAA,ArkhipkinA,PierceGJ,SemmensJ,SteerM,etal.Global proliferationofcephalopods.CurrBiol.2016;26:PR406-7.

EndlerJA. Apredator'sviewofanimalcolorpatterns.In:HechtMK,Steere WC,WallaceB,editors.Evolutionarybiology. NewYork, NY:Springer;1978.p.319-64.

FloresEEC,IgarashiS,MikamiT.Studiesonsquidbehaviorinrelatio ntofishing: III.ontheoptomotorresponseofsquid, *Todarodespacificus*Steenstrup,tovariouscolors.BullFishHokkaido Univ.1978;29:131-40.

FoodandAgricultureOrganizationoftheUnitedNations[FAO] .Fisheryandaquaculturestatistics2017.Rome: FAO;2019.

GillyWF,MarkaidaU,BaxterCH,BlockBA,BoustanyA, ZeidbergL,etal.Verticalandhorizontalmigrationsbythejumb osquid*Dosidicusgigas*revealedbyelectronictagging. MarEcolProgSer.2006;324:1-17.

HunsickerME,EssingtonTE,WatsonR,SumailaUR.Thecon-tributionofcephalopodstoglobalmarinefisheries:canwehave oursquidandeatthemtoo? FishFish.2010;11:421-38.

HurstRJ,BallaraSL,MacGibbonD,TriantafillosL.Fisherycharacterisationandstandardised CPUEanalysesforar-rowsquid(*Nototodarusgouldi*and*N.sloanii*),1989–90to 2007–08,andpotentialmanagementapproachesforsouth-ernfisheries.Wellington:MinistryforPrimaryIndustries; 2012.ReportNo.:2012/47.

JerepP,RoperCFE.Cephalopodsoftheworld:anannotatedandill ustratedcatalogueofcephalopodspeciesknowntodate:vol2 .myopsidandoegopsidsquids. Rome:FAO; 2010.

Kang C, StevensM, Moon JY, LeeSI, Jablonski PG. Camouflage through behavior in moths: the role of background matching and disruptive coloration. Behavioral Ecology 2015;26(1):45–54.

KoopmanM,KnuckeyI,CahillM.Improvingthelocationandtarge tingofeconomicallyviableaggregationsofsquidavailabletothe squidjiggingmethodandthefleet'sabilitytocatchsquid.Canberr a:AustralianFisheriesManagementAuthority;2018.

MallawaA,PaloSM,Musbir.StudyonbaganRambofisheriesinBar ruwaters,MakassarStrait.Makassar:ResearchInsti-tuteofHasanuddinUniversity;1991.

MappesJ,MarplesN, EndlerJA.Thecomplexbusinessofsur-vivalbyaposematism.TrendsEcolEvol.2005;20:598-603.

MarchesanM,SpotoM,VerginellaL,FerreroEA.Behaviouraleffect sofartificiallightonfishspeciesofcommercialinter-est.FishRes.2005;73:171-85.

MochidaK,ZhangWY,TodaM. Thefunctionofbodycolor-ationofthehaicoralsnake*Sinomicrurusjaponicusboett-geri*.ZoolStud.2015;54:33.

Morales-BojórquezE,Cisneros-MataMA,Nevárez-Martinez MO,Hernández-Herrera A.Reviewofstockassessmentandfisherybiologyof*Dosidicus gigas*intheGulfofCali- fornia,Mexico.FishRes.2001;54:83-94.

NigmatullinCM,NesisKN,ArkhipkinAI.Areviewofthebiolog yofthejumbosquid*Dosidicusgigas*(Cephalopoda: Ommastrephidae).FishRes.2001;54:9-19.

OkutaniT,TungIH.Reviewsofbiologyofcommerciallyim-portantsquidsinJapaneseandadjacentwaters:I.*Symplec-toteuthisoualaniensis*(lesson).Veliger.1978;21:87-94.

PaighambariSY, DaliriM,MemarzadeM.Theeffectsofjigcol-oranddepthvariationoncatchratesofpurplebackflyingsquid,*Sthenoteuthisoualaniensis*(Lesson,1830)inIranianwatersofthe OmanSea.CaspJApplSciRes. 2012;1:1-5.

PierceGJ,SantosMB,MacLeodCD,WangJ,ValavanisV,ZuurAF.Mo dellingenvironmentalinfluencesonsquidlifehis-tory,distribution,andabundance.In:Proceedingsofthe GLOBEC-CLIOTOPWG3Workshop;2006;Hawaii,HI, USA.

PratasikSB,LalamentikLTX,ManoppoL,BudimanJ.Deepseasquid inSulawesiSea,NorthSulawesiprovince,Indonesia. Biodiversitas.2022;23:1774-9.

RaoKS.Cephalopodfishing.In:ProceedingsoftheAquacultureFoundationofIndia&TheFisheriesTechnocratsForum;1995;Chennai,India.

RezaFA,UmrohU, UtamiE.Theeffectofbaittypesonsquidcapture*Loligo*sp.inTuingwatersofBangkaRegency.JAquatropicaAsia.2019;4:20-5.

RobertsMJ,SauerWHH.Environment:thekeytounderstandingtheSouthAfricanchokkasquid(*Loligovulgarisreynaudii*)lifecycleandfishery?AntarctSci.1994;6:249-58.

RodhousePGK,PierceGJ,NicholsOC,SauerWHH,ArkhipkinAI,LaptikhovskyVV,etal.Environmentaleffectsoncephalopodpopulationdynamics:implicationsformanagementoffisheries.AdvMarBiol.2014;67:99-233.

RoperCFE,SweeneyMJ,NauenC.FAOspeciescatalogue:vol.3. cephalopodsoftheworld:anannotatedandillustratedcatalogueofspeciesofinteresttofisheries.Rome:FAO;1984.

SolomonOO,AhmedOO.Fishingwithlight: ecological consequencesforcoastalhabitats.IntJFishAquatStud. 2016;4:474-83.

Stewart JS,GillyWF,FieldJC,PayneJC.Onshore–offshore movementofjumbosquid(*Dosidicusgigas*)onthecontinentalshelf.DeepSeaResIITopStudOceanogr. 2013;95:193-6.

ToledoLF,HaddadCFB.Colorsandsomemorphologicaltraitsasdefensivemechanismsinanurans.IntJZool. 2009;2009:910892.

TungIH.Onthefisheryandbiologyofthesquid,*Ommastrephesbartramii*,inthenorthwestPacificOcean.RepInstFishBiolTaipei.1981;3:12-37.

UlaşA,AydinI.Theeffectsofjigcolorandlunarbrightoncoastalsquidjigging.AfrJBiotechnol.2011;10:1721-6.

VossGL.Cephalopodresourcesoftheworld.Rome:FAO;1973.

WormsJ.Worldfisheriesforcephalopods:asynopticoverview. In:CaddyJF,editor.Advancesinassessmentofworldcephalopodresources.Rome:FAO;1983.p.1-20.

YamashitaY,MatsushitaY,AzunoT.CatchperformanceofcoastalsquidjiggingboatsusingLEDpanelsincombinationwithmetalhalidelamps.FishRes.2012;113:182-9.

YoshikawaN.FisheriesinJapan:squidandcuttlefish.Tokyo: JapanMarineProductsPhotoMaterialsAssociation;1978.

YuW,ChenX,YiQ,ChenY,ZhangY.Variabilityofsuitablehabitatofwesternwinter-springcohortforneonflyingsquidinthenorthwestPacificunderanomalousenvironments.PLOSONE.2015;10:e0122997.

https://doi.org/10.47853/FAS.2023.e28

RESEARCH ARTICLE
eISSN 2234-1757
Fish Aquat Sci. 2023;26(5):1-000
https://doi.org/10.47853/FAS.2023.e28
FAS Fisheries and Aquatic Sciences

Behavioral response of purpleback flying squid *Sthenoteuthis oualaniensis* (Mollusk; Cephalopod) to the flashlight artificial bait colors

Lefrand Manoppo[1], Silvester Benny Pratasik[2,*], Effendi P. Sitanggang[1], Lusia Manu[2], Juliaan Cheyvert Watung[3]

[1] *Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, North Sulawesi 95115, Indonesia*
[2] *Fisheries Resources Management, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, North Sulawesi 95115, Indonesia*
[3] *Aquaculture, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, North Sulawesi 95115, Indonesia*

Abstract

This study aimed to know the response of deep-sea squid *Sthenoteuthis oualaniensis* to the light colors of the artificial bait. This experiment used the commercial artificial flashlight baits commonly sold in the fishing shop. The bait has several different light color combinations. The light colors were modified into several light colors by inactivating certain colors and used as treatments. The study is expected to be able to find flashlight bait's most effective color for squid fishing. We applied red-green, green, blue, and commercial bait lights in this study. Each treatment has 3 replications. The effect was expressed as the amount of squid caught. Data were analyzed by one-way analysis of variance. Results showed a significant effect on the number of squid catches. There was significantly different squid catches among the treatments. It indicates that this artificial flashlight bait could be developed to maximize squid catches. This finding can be used for the local fishermen's income and the squid fisheries development.

Keywords: Commercial jig, Modification, Effect, Catch

Introduction

The exploitation of fisheries resources starts from a basic human need to obtain animal protein sources. Squid is one of the protein sources from the ocean, and nearly all body parts are edible. Since 1950, capture production of cephalopods has continued to grow (Doubleday et al., 2016; Hunsicker et al., 2010), with total commercial annual catches between 3.5 and 4.9 million tons in 2008–2017 (FAO, 2019), almost 4.6 times higher than that of the 1950s. Cephalopods on average support approximately 15% and 20% of marine fishery landings and landed values, respectively (FAO, 2019; Hunsicker et al., 2010). This group has unique life history characteristics, including rapid growth, short lifespan, and semelparous reproductive strategy, giving them both sensitivity and resilience to anthropogenic exploitation and oceanographic variability (Rodhouse et al., 2014). The species within the family Ommastrephidae support approximately 33.8% of the global cephalopod's landings (FAO, 2019). This group is recognized

Received: Aug 15, 2022 **Revised:** Jan 24, 2023 **Accepted:** Jan 26, 2023
***Corresponding author:** Silvester Benny Pratasik
Fisheries Resources Management, Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, North Sulawesi 95115, Indonesia
Tel: +62-431-6868027, **E-mail:** spjong07@yahoo.com

as voracious and adaptable predators of a broad range of prey including small crustaceans and fishes at early life stages and shift to micronekton, larger fishes, and cephalopods (including cannibalism) as they grow (Alegre et al., 2014; Nigmatullin et al., 2001). Despite its economic importance, the offshore oceanic squid resources' exploitation rate is relatively low (Worms, 1983). The flying squids (Ommastrephidae; Oegopsid) cover about 65% of the world's commercial cephalopods (Brunetti, 1990; Roper et al., 1984) with a total of about 2.6 million in 1991 (FAO, 1993). The flying squids *Sthenoteuthis oualaniensis* (Lesson) and *Ommastrephes bratamii* are the oceanic species of this family that are distributed from the Indo-Pacific to the Indian Ocean. According to Voss (1973), the potential of the purpleback flying squids in the Central Eastern Pacific is at least 100,000 metric tons. This species is caught commercially in the eastern and southern East China Sea, from Taiwan to Okinawa by hook and line with light at night (Okutani & Tung, 1978; Tung, 1981; Yoshikawa, 1978). The deep-sea squids caught by traditional fishermen of Manado Bay, North Sulawesi, in the Sulawesi Sea have been identified as a dwarf form of *S. oualaniensis* (Pratasik et al., 2022). These species are highly migratory and undertake diel vertical migrations of several hundred meters and seasonal migrations between the shelf and open ocean (Gilly et al., 2006; Stewart et al., 2013) so that they can act as important linkages between both neritic and oceanic food webs (Arkhipkin, 2013).

There are numerous studies on bait types to find the highest catch, from fish and shrimp flesh, live bait, and artificial bait. Fish and squids were observed to be attracted to squid jigging vessels due to the phototaxis (Rao, 1996). It is related to their behavior to avoid predators or enhance feeding efficiency (Solomon & Ahmed, 2016), and their response depends upon species, ontogenic development, light source characteristics, intensity, color, and wavelength (Mallawa et al., 1991). Therefore, fishermen catch squid using light that illuminates in water as well as jigs to attract the squids to aggregate and bite the jigs (Asokan & Krishnan, 2021). It relies on the artificial bait of shrimp-like siliconized jig fishing (Altinagac, 2006; Aydin & İlkyaz, 2021; Paighambari et al., 2012; Reza et al., 2019; Ulaş & Aydin, 2011). Other studies on hand-line fishing are also done using different colors of shrimp-shaped jigs (Altinagac, 2006; Aydin & İlkyaz, 2021; Paighambari et al., 2012; Ulaş & Aydin, 2011). Squid fishing in North Sulawesi is done by traditional fishermen using 5 to 7 M-boat and artificial bait either shrimp-like bait or other bait types (Fig. 1).

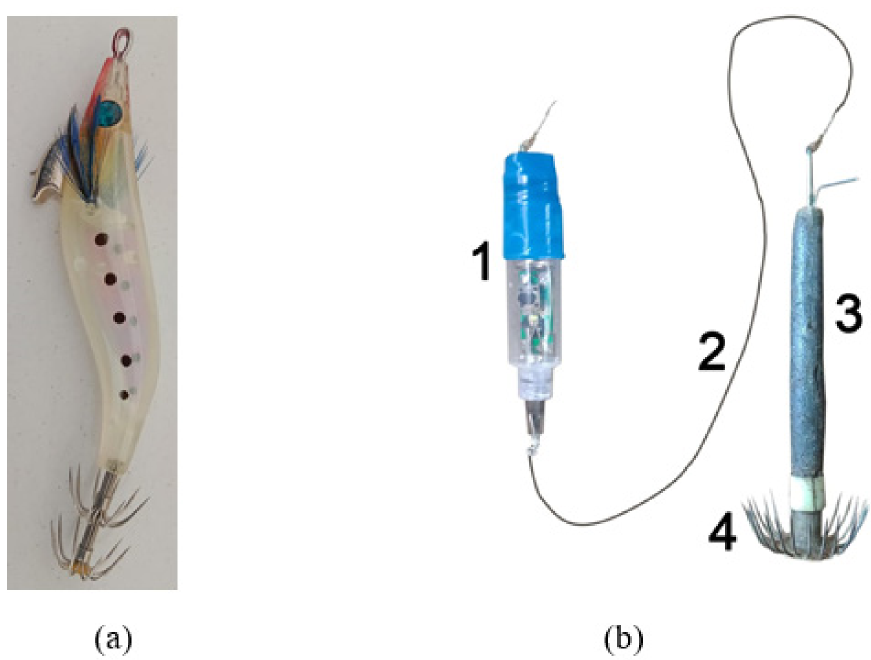


Fig. 1. Artificial bait. (a) Shrimp-like bait and (b) flashlight jig. 1) Flashlight; 2) one-meter line; 3) lead; 4) hook.

https://doi.org/10.47853/FAS.2023.e28

For deep-sea squid *S. oualaniensis* fishing, the fishermen use a mini-battery-supported flashlight artificial bait sold in the fishing stores. The flashlight artificial bait contains several different alternately blinking light colors to get the squid to bite. This study modifies the light colors to find the best modification of light color against the catches.

Materials and Methods

This study was carried out from June to July 2020. Traditional fishermen catch deep-sea squids *S. oualaniensis* in the Sulawesi Sea, North Sulawesi, at night (Fig. 2). The flashlight bait is facilitated with a mini-battery to be able to produce several different light colors to attract the squid. The flashlight was connected by a one-meter line to the hook working also as a lead. In fishing operations, the lead was coated with fish flesh as bait.

This experiment modified the standard commercial flashlight bait sold in the fishing shop to produce different light colors: red-green, blue, green, and red. These different light colors were used in 10 fishing trips. Twelve skillful fishermen were used in this experiment in which they were divided into 4 groups of 3 people in 4 separate traditional boats (7 m long) to operate each light color in the same fishing ground. The common commercial flashlight bait was also used as a control treatment. Each line used only one jig and all jig-fishing activities were carried out at the same time. The fishing line was lowered down to the depth range of 20–25 M in the deep sea of Sulawesi Sea waters and jigged. This fishing depth is consistent with the dispersal range peak of *S. oualaniensis* (Jerep & Roper, 2010).

The use of the red-colored bait was eventually terminated because it was always cut off and lost. The experiment utilized only commercial bait, red-green bait, blue bait, and green bait as treatment with 3 replications represented by 3 local skillful fishermen for each bait light color. Data collections were squid catches. The catch data were analyzed with one-way analysis of variance facilitated by statistical software for comparisons. The difference between treatments was then tested using Tukey's honestly significant difference (HSD) procedure.

Results

This study caught a total of 30,687 squids *S. oualaniensis* during the fishing experiment in the Sulawesi Sea, North Sulawesi. Different light color applications highly significantly influenced

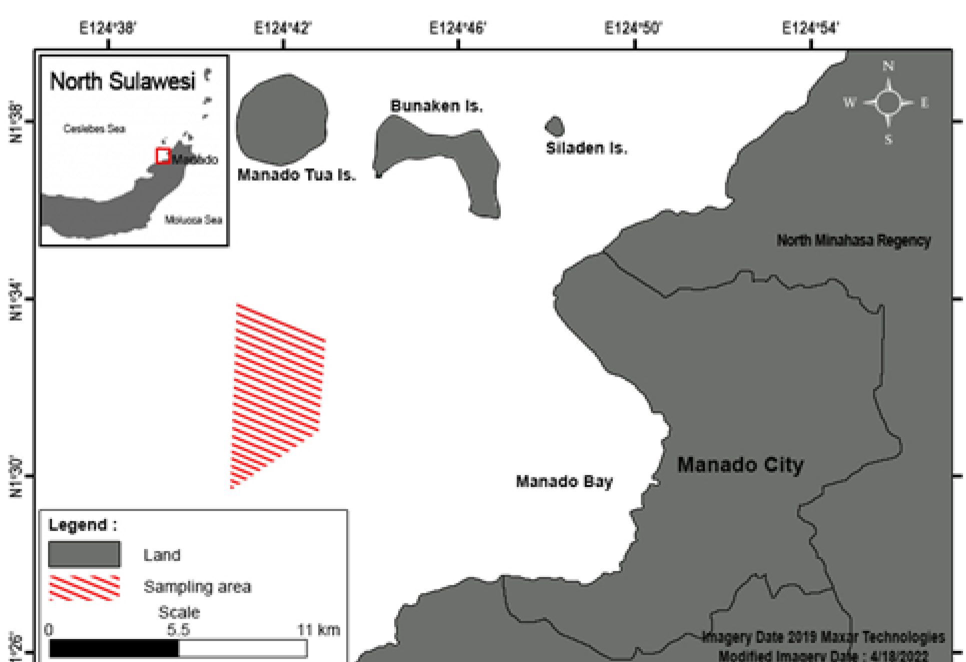


Fig. 2. Sampling site.

the number of squid catches ($p < 0.001$). Analysis of variance demonstrates that both trip and bait light color influence the squid catches (Table 1).

Tukey's HSD test revealed that *S. oualaniensis* differently responded to the bait's light colors. All treatment applications gave a significantly different number of catches. Comparisons between treatments showed that all bait light color modifications gave a higher number of catches than the commercial one (Table 2).

The significantly different squid catches are also indicated by the mean number of squid catches (Fig. 3). The green-lighted jig yielded the highest mean squid catches, 377.37 (39.46%), followed by blue light color, 268.3 (28.06%), then red-green, 213.43 (22.32%), and the lowest catches in the commercial artificial bait, 97.13 (10.16%) (Table 2 and Fig. 3). Multiple comparisons between treatment applications yielded 6 pairs of comparisons and indicated that all treatment flashlight jig colors yielded significantly different squid catches, in which single light colors also give the squid a higher response to taking the lure (Table 2).

Discussion

Jigging is an essential fishing method to exploit squids selectively and avoid overexploiting to conserve resources and energy (Asokan & Krishnan, 2021). It helps to adjust operational depth according to the concentration depth of squids. They are attracted to lights and fast-moving bait or any bait-like object. A typical jig consists of a shrimp or stalk-like body made of flexible plastic with one to three hooks or more sharp barbless steel hooks at the end. Other jigs are facilitated with the mini battery-supported light blinking.

Squids are known as color-blinded animals, but the degree of contrast is important for squid behavior to attack the jig (Flores et al., 1978). The use of a flashlight jig, in fact, gave a stronger degree of contrast in the water column at night fishing than the use of light above the water and could give a stronger stimulus to the squid to attack the fish flesh bait connected to blinking light. The flashlight jig also has a higher degree of contrast than the shrimp-like siliconized jig so that the squid more sensitively responds to the flashlight jig color in the water column. The flashlight acts as a squid-aggregating device, while the squid feeds on the fish's flesh, then caught by the hook. The flashlight jig could help the purpleback flying squid get the bait. All squids were hooked on the arms, indicating that the squids are feeding on the fish's flesh coated on the lead. On the other hand, cephalopods (squid, cuttlefish, and octopus) are well known as voracious predators of many preys, such as fish and crustaceans, or even have cannibalism behavior, so the contrast

Table 1. Analysis of variance on the effect of artificial bait light colors on the number of catches

Source of variance	Sum of squares	*Df*	Mean square	*F*-ratio	*p*-value
Main effects					
A: Trip	85,653.0	9	9,517.0	24.96	0.0000
B: Bait light color	1.22351×10^{-6}	3	407,836	1,069.59	0.0000
A-B interactions	16,791.1	27	621.892	1.63	0.0488
Residual	30,504.0	80	381.3		
Total	1.35646×10^{-6}	119			

Table 2. Multiple comparisons between treatment applications

Bait light color comparisons	Difference	+/– Limits
BLUE–COM	171.167*	13.229
BLUE–GREEN	–109.067*	13.229
BLUE–RED-GREEN	54.8667*	13.229
COM–GREEN	–280.233*	13.229
COM–RED-GREEN	–116.3*	13.229
GREEN–RED-GREEN	163.933*	13.229

*Significant difference.

https://doi.org/10.47853/FAS.2023.e28

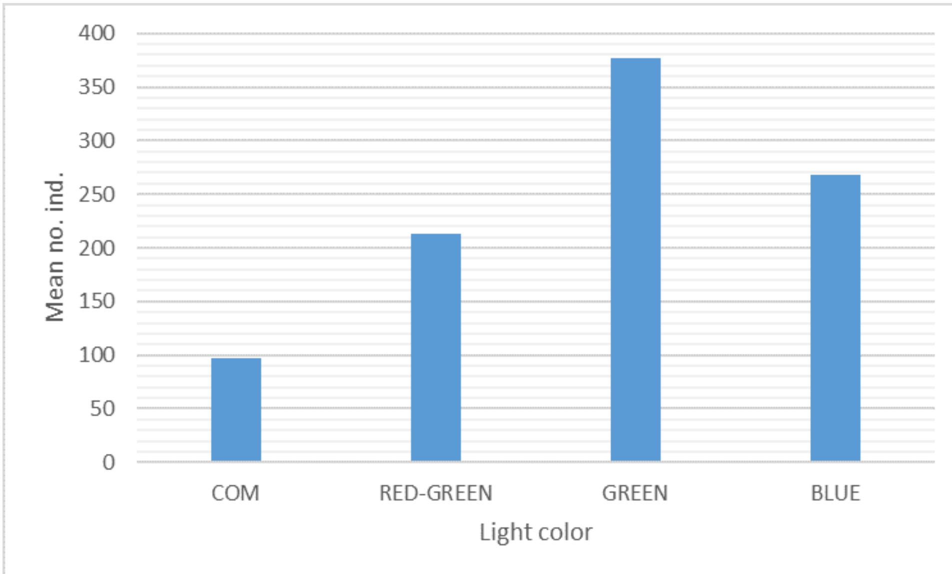


Fig. 3. Mean catch of squid *Sthenoteuthis oualaniensis* during the study.

moving objects in the water column could indicate the presence of moving prey.

Furthermore, the present study revealed that the modified light colors of the artificial bait caught a higher number of deep-sea squid *S. oualaniensis* in the Sulawesi Sea than the common commercial artificial bait sold in the fishing store with a combination of several different colors. There was also a significantly different effect of all light color modifications on the squid catches with the highest catch in the green light. The low attacking preference of the purpleback flying squid to the multiple light colors could result from the squid's perception of the blinking multiple colors of the flashlight bait as the aposematic coloration of the prey, in which the animal shows the unpalatability or toxicity through warning coloration. This defense mechanism is widely discussed by Endler (1978), Mappes et al. (2005), Mochida et al. (2015), Stevens (2007), and Toledo & Haddad (2009). Aposematism is commonly found across the animal kingdom as a defense mechanism, and it could either be chemicals, such as toxins, harmful secretions, and venoms, or physical defense, such as spines, bites, and stings (Mappes et al., 2005).

This finding is in agreement with Altinagac (2006) and Paighambari et al. (2012) that the green bait color is more efficient in squid jig fishing even though it does not have a significantly different effect from the use of red color in Turkish waters (Altinagac, 2006) and the blue color (Paighambari et al., 2012) on the catch rate of purpleback flying squids in Iranian waters of the Oman Sea. The sensitivity of fish and some of their food animals to blue and green colors is higher because of the long wavelengths that make them penetrate deeper into the water column (Solomon & Ahmed, 2016). The use of dark green jig color is also shown by the traditional fishermen, particularly in North Minahasa, North Sulawesi, as a potential bait color for demersal fish jig fishing (field obs.). Nevertheless, Ulaş & Aydin (2011) found that the red jig is the most efficient in squid *Loligo vulgaris* Lamarck (1798) fishing on the Middle Eastern Coast of Aegean Sea, Turkey. All those findings were obtained using the shrimp-like siliconized bait. The local fishermen of North Sulawesi commonly use the shrimp-like siliconized jig to fish shallow water squids *Sepioteuthis lessoniana.* A different finding is shown by Arnupapboon et al. (2008) that the squid moves to white and blue more often than green, while the red color seemed not to attract the squids.

This fishing experiment reconfirms the previous finding concerning the most efficient bait color and shows that the use of single bait light color yielded higher catches than that of multiple colors ($p < 0.05$). This study did not use the red light color as a treatment, since the red-lighted bait was always taken and cut off. Therefore, we had to use a wireline to the bait to know what causes the loss and found that the red light color was taken by the cutlassfish *Trichiurus* sp. The difference in squid's preference for jig color could result from environmental conditions with locality, such as predator-prey interactions that may alter the feeding behavior on-site and species. The presence of a higher level of the predator, such as cutlassfish *Trichiurus* sp., particularly in Sulawesi waters which is also attracted to the red-light jig has diminished the chance of the deep-sea squids *S. oualaniensis* to take the red jig or the squid *S. oualaniensis* is vulnerable to predation risk for feeding on the red-light jig.

According to Asokan & Krishnan (2021), the efficiency of squid jigging is influenced by jig structure, jigging motion, light intensity, sea state, and sea surface temperature (Cabanellas-Reboredo et al., 2012; Roberts & Sauer, 1994; Yu et al., 2015), wind speed, moon phase, and atmospheric pressure (Cabanellas-Reboredo et al., 2012), sea surface height anomaly (Yu et al., 2015), turbidity (Roberts & Sauer, 1994), chlorophyll (Hurst et al., 2012), salinity (Yu et al., 2015), and large scales climate predictors, such as the Southern Oscillation Index and the North Atlantic Oscillation (Morales-Bojórquez et al., 2001; Pierce et al., 2006; Roberts & Sauer, 1994), etc. These factors will influence the catches, recruitment, migration (Koopman et al., 2018), and distribution of the squids. During squid jigging with lights, the quality of light (e.g., wavelength), the quantity of light (e.g., power), and the arrangement of fishing lights affect the squid's attraction. These factors create underwater irradiance levels and distribution influenced by the optical characteristics of seawater, and it influences squid behavior during fishing (Arakawa et al., 1998; Yamashita et al., 2012). According to Cabanellas-Reboredo et al. (2012), environmental variables, such as sea surface temperature, atmospheric pressure, and moon cycle can also influence squid catches. This experiment focused only on the effect of different jig light colors on the squid bites since the fishing was conducted in a single lunar cycle with different tide conditions. The jiggers took advantage of wind or current direction to position their boats in certain areas to avoid being drifted too far out of the mainland due to the use of the small boat (approximately 5–7 M long).

These findings showed that all light color modifications of the multiple flashlight-squid baits have contributed to the artificial squid flashlight bait development concerning the squid fishing effectivity. Light colors also influenced the feeding behavior of *S. oualaniensis*, and the single color gave the squid a higher response to getting the lure than the multiple colors. The highest squid catch was recorded in the green light color and the lowest was in the commercial artificial bait. Therefore, the present study has contributed to developing the mini-battery-supported artificial bait for effective exploitation to maximize offshore squid production and fisheries development so that the use of offshore squid resources could be increased. This information is also useful for traditional fishermen to increase their personal income through deep-sea squid fishing. Nevertheless, more studies on squid feeding behavior and other influencing environmental factors are needed for future squid population sustainability.

Competing interests

No potential conflict of interest relevant to this article was reported.

Funding sources

Not applicable.

Acknowledgements

We would greatly appreciate the Rector of Sam Ratulangi University and the Dean of the Faculty of Fisheries and Marine Sciences who provided a small research grant. High appreciation is also addressed to Mr. Ponny Telleng who led the local fishermen of Manado Bay in fishing operations.

Availability of data and materials

Upon reasonable request, the datasets of this study can be available from the corresponding author.

Ethics approval and consent to participate

This article does not require IRB/IACUC approval because there are no human and animal participants.

ORCID

Lefrand Manoppo https://orcid.org/0000-0002-9154-4470
Silvester Benny Pratasik https://orcid.org/0000-0002-3765-509X
Effendi P. Sitanggang https://orcid.org/0000-0002-0256-2950
Lusia Manu https://orcid.org/0000-0001-6200-4451
Juliaan Cheyvert Watung https://orcid.org/0000-0002-8327-6488

References

Altinagac U. Effect of jigs color to catching efficiency in the squid fishing in Turkey. Pak J Biol Sci. 2006;9:2916-8.

Arakawa H, Choi S, Arimoto T, Nakamura Y. Relationship between underwater irradiance and distribution of Japanese common squid under fishing lights of a squid jigging boat. Fish Sci. 1998;64:553-7.

Arkhipkin AI. Squid as nutrient vectors linking Southwest Atlantic marine ecosystems. Deep Sea Res II Top Stud Oceanogr. 2013;95:7-20.

Arnupapboon S, Awaiwanont K, Monton A, Suphachai A, Bundit C. Boosting the development of responsible squid light fishery: assessment of squid feeding behavior. Fish People. 2008;6:44-7.

Asokan K, Krishnan AR. Techniques to squid jigging in India: a review. J Entomol Zool Stud. 2021;9:415-22.

Aydin C, İlkyaz AT. Catching performance and catching efficiency of siliconized baits in handline fishery. J Agric Sci. 2021;27:219-30.

Brunetti NE. Description of *Rhynchoteuthion* larvae of *Illex argentinus* from the summer spawning subpopulation. J Plankton Res. 1990;12:1045-57.

Cabanellas-Reboredo M, Alós J, Palmer M, Morales-Nin B. Environmental effects on recreational squid jigging fishery catches. ICES J Mar Sci. 2012;69:1823-30.

Doubleday ZA, Prowse TAA, Arkhipkin A, Pierce GJ, Semmens J, Steer M, et al. Global proliferation of cephalopods. Curr Biol. 2016;26:PR406-7.

Endler JA. A predator's view of animal color patterns. In: Hecht MK, Steere WC, Wallace B, editors. Evolutionary biology. New York, NY: Springer; 1978. p. 319-64.

Flores EEC, Igarashi S, Mikami T. Studies on squid behavior in relation to fishing: III. on the optomotor response of squid, *Todarodes pacificus* Steenstrup, to various colors. Bull Fish Hokkaido Univ. 1978;29:131-40.

Food and Agriculture Organization of the United Nations [FAO]. Fishery and aquaculture statistics 2017. Rome: FAO; 2019.

Gilly WF, Markaida U, Baxter CH, Block BA, Boustany A, Zeidberg L, et al. Vertical and horizontal migrations by the jumbo squid *Dosidicus gigas* revealed by electronic tagging. Mar Ecol Prog Ser. 2006;324:1-17.

Hunsicker ME, Essington TE, Watson R, Sumaila UR. The contribution of cephalopods to global marine fisheries: can we have our squid and eat them too? Fish Fish. 2010;11:421-38.

Hurst RJ, Ballara SL, MacGibbon D, Triantafillos L. Fishery characterisation and standardised CPUE analyses for arrow squid (*Nototodarus gouldi* and *N. sloanii*), 1989–90 to 2007–08, and potential management approaches for southern fisheries. Wellington: Ministry for Primary Industries; 2012. Report No.: 2012/47.

Jerep P, Roper CFE. Cephalopods of the world: an annotated and illustrated catalogue of cephalopod species known to date: vol 2. myopsid and oegopsid squids. Rome: FAO; 2010.

Koopman M, Knuckey I, Cahill M. Improving the location and targeting of economically viable aggregations of squid available to the squid jigging method and the fleet's ability to catch squid. Canberra: Australian Fisheries Management Authority; 2018.

Mallawa A, Palo SM, Musbir. Study on bagan Rambo fisheries in Barru waters, Makassar Strait. Makassar: Research Institute of Hasanuddin University; 1991.

Mappes J, Marples N, Endler JA. The complex business of survival by aposematism. Trends Ecol Evol. 2005;20:598-603.

Marchesan M, Spoto M, Verginella L, Ferrero EA. Behavioural effects of artificial light on fish species of commercial interest. Fish Res. 2005;73:171-85.

Mochida K, Zhang WY, Toda M. The function of body coloration of the hai coral snake *Sinomicrurus japonicus boettgeri.* Zool Stud. 2015;54:33.

Morales-Bojórquez E, Cisneros-Mata MA, Nevárez-Martinez MO, Hernández-Herrera A. Review of stock assessment and fishery biology of *Dosidicus gigas* in the Gulf of California, Mexico. Fish Res. 2001;54:83-94.

Nigmatullin CM, Nesis KN, Arkhipkin AI. A review of the biology of the jumbo squid *Dosidicus gigas* (Cephalopoda: Ommastrephidae). Fish Res. 2001;54:9-19.

Okutani T, Tung IH. Reviews of biology of commercially important squids in Japanese and adjacent waters: I. *Symplectoteuthis oualaniensis* (lesson). Veliger. 1978;21:87-94.

Paighambari SY, Daliri M, Memarzade M. The effects of jig color and depth variation on catch rates of purpleback flying squid, *Sthenoteuthis oualaniensis* (Lesson, 1830) in Iranian waters of the Oman Sea. Casp J Appl Sci Res. 2012;1:1-5.

Pierce GJ, Santos MB, MacLeod CD, Wang J, Valavanis V, Zuur AF. Modelling environmental influences on squid life history, distribution, and abundance. In: Proceedings of the GLOBEC-CLIOTOP WG3 Workshop; 2006; Hawaii, HI, USA.

Pratasik SB, Lalamentik LTX, Manoppo L, Budiman J. Deep sea squid in Sulawesi Sea, North Sulawesi province, Indonesia. Biodiversitas. 2022;23:1774-9.

Rao KS. Cephalopod fishing. In: Proceedings of the Aquaculture Foundation of India & The Fisheries Technocrats Forum; 1995; Chennai, India.

Reza FA, Umroh U, Utami E. The effect of bait types on squid capture *Loligo* sp. in Tuing waters of Bangka Regency. J Aquatropica Asia. 2019;4:20-5.

Roberts MJ, Sauer WHH. Environment: the key to understanding the South African chokka squid (*Loligo vulgaris reynaudii*) life cycle and fishery? Antarct Sci. 1994;6:249-58.

Rodhouse PGK, Pierce GJ, Nichols OC, Sauer WHH, Arkhipkin AI, Laptikhovsky VV, et al. Environmental effects on cephalopod population dynamics: implications for management of fisheries. Adv Mar Biol. 2014;67:99-233.

Roper CFE, Sweeney MJ, Nauen C. FAO species catalogue: vol. 3. cephalopods of the world: an annotated and illustrated catalogue of species of interest to fisheries. Rome: FAO; 1984.

Solomon OO, Ahmed OO. Fishing with light: ecological consequences for coastal habitats. Int J Fish Aquat Stud. 2016;4:474-83.

Stewart JS, Gilly WF, Field JC, Payne JC. Onshore–offshore movement of jumbo squid (*Dosidicus gigas*) on the continental shelf. Deep Sea Res II Top Stud Oceanogr. 2013;95:193-6.

Toledo LF, Haddad CFB. Colors and some morphological traits as defensive mechanisms in anurans. Int J Zool. 2009;2009:910892.

Tung IH. On the fishery and biology of the squid, *Ommastrephes bartramii*, in the northwest Pacific Ocean. Rep Inst Fish Biol Taipei. 1981;3:12-37.

Ulaş A, Aydin I. The effects of jig color and lunar bright on coastal squid jigging. Afr J Biotechnol. 2011;10:1721-6.

Voss GL. Cephalopod resources of the world. Rome: FAO; 1973.

Worms J. World fisheries for cephalopods: a synoptic overview. In: Caddy JF, editor. Advances in assessment of world cephalopod resources. Rome: FAO; 1983. p. 1-20.

Yamashita Y, Matsushita Y, Azuno T. Catch performance of coastal squid jigging boats using LED panels in combination with metal halide lamps. Fish Res. 2012;113:182-9.

Yoshikawa N. Fisheries in Japan: squid and cuttlefish. Tokyo: Japan Marine Products Photo Materials Association; 1978.

Yu W, Chen X, Yi Q, Chen Y, Zhang Y. Variability of suitable habitat of western winter-spring cohort for neon flying squid in the northwest Pacific under anomalous environments. PLOS ONE. 2015;10:e0122997.

https://doi.org/10.47853/FAS.2023.e28

Re: [FAS] Author proofreading request Yahoo/Inbox

거목문화사 <guhmok@guhmok.com> May 23 at 9:40 AM
To: spjong07@yahoo.com

Dear author
We edited your article.
We would like to confirm that it has been modified.
If there are no modification, it will be published on May 31.

Best regards,
Guhmok Publising

[거목문화사] 학술지 편집/인쇄 · 홈페이지 · 논문투고시스템 · JATS XML
04549 서울시 중구 을지로 148 중앙데코플라자 609호
TEL(대표): 02-2277-3324, FAX: 02-2277-3390
Homepage: http://www.guhmok.com E-mail: guhmok@guhmok.com
웹하드: http://www.webhard.co.kr ID: guhmok PW: 22773324

2023년 5월 20일 (토) 오후 10:02, Yahoo Mail <spjong07@yahoo.com>님이 작성:

Dear Sir,
I herewith send you the revised paper. I would also like to thank you for editing the references in the text. We went through the whole paper (YELLOW). We replaced FAO (1993) with FAO (2003) and Stevens (2007) with Kang et al. (2015). The running title: Response of purpleback flying squid to bait color. I hope the paper could have met your requirements. Thank you.

Silvester B. Pratasik
(Corresponding author)

On Wednesday, May 17, 2023, 09:27:56 AM GMT+8, 거목문화사 <guhmok@guhmok.com> wrote:

Hello. Nice to meet you.
We are a **Guhmok publishing company** that is editing and proofreading FAS (Fisheries and Aquatic Sciences).

This month, FAS will be published.

Please, check the attached file (PDF).
Please refer to the pdf that has been marked for correction, and please indicate what you want to edit in the final edited pdf.
If you want change anything, you can change through E-mail message and PDF's memo.
If Authors have IRB/IACUC approval, please provide the institution and approval number.
ex) This research has been approved by the Institutional Animal Care and Use Committee (IACUC) of Kongju National University, Korea (KNU-IACUC-2018-xxx).

Please, let me know easily and accurately.
For example, let me know about accurate page, figure number and table number.

The basic poorfreading principle is as follows.
1. Please take a close look at the revised part and be sure to mention the part we made the wrong correction.
2. We have found the references one by one and modified them in accordance with the regulations.
 - Please confirm the revision, and if there is anything that needs to be changed, please reply by e-mail.
 - In the case of reports, old books, etc., it is difficult to confirm the accuracy of the references on the internet. So, author must confirm.
 - If you have not checked the original text and used it as a reference, please consider the changes.
 - There are many cases in which references are copied and used in other papers, and references are made to incorrect or missing references.
 - When copying a reference section of another article, many references are cited with incorrect or missing references.
3. We have edited all papers in accordance with the editorial committee guidelines, which can not be changed until approval by the editorial committee.
 - We used a single space in front of every unit mark, but there is no space in front of the %, °, and °C marks. Etc…
4. If the abbreviated words are first appeared, please write the full name and abbreviate it afterwards.
5. The abbreviation used in the table should be given to the full name at the bottom so that you can see it separately from the main text.
6. All author's department, institution (university), city and country are required.
7. The memos in PDF file are an important part, so check carefully.

Please reply by May 20, 2023, 11:00 am.

***If there are two corresponding authors, please send the revised contents into one file.**

If there are no edits, please reply with the message that you do not need to make any changes.

Thank you for your cooperation.

Best regards,
Guhmok Publising

[거목문화사] 학술지 편집/인쇄 · 홈페이지 · 논문투고시스템 · JATS XML
04549 서울시 중구 을지로 148 중앙데코플라자 609호
TEL(대표): 02-2277-3324, FAX: 02-2277-3390
Homepage: http://www.guhmok.com   E-mail: guhmok@guhmok.com
웹하드: http://www.webhard.co.kr   ID: guhmok   PW: 22773324

1 File 784.8kB

03-FAS(Research article)_2022-0089_Silvester Benny Pratasik.pdf
785kB

Re: [FAS] Author proofreading request

Yahoo/Inbox

거목문화사 <guhmok@guhmok.com>
To: spjong07@yahoo.com

May 23 at 9:40 AM

Dear author
We edited your article.
We would like to confirm that it has been modified.
If there are no modification, it will be published on May 31.

Best regards,
Guhmok Publising

[거목문화사] 학술지 편집/인쇄 · 홈페이지 · 논문투고시스템 · JATS XML
04549 서울시 중구 을지로 148 중앙데코플라자 609호
TEL(대표): 02-2277-3324, FAX: 02-2277-3390
Homepage: http://www.guhmok.com E-mail: guhmok@guhmok.com
웹하드: http://www.webhard.co.kr ID: guhmok PW: 22773324

2023년 5월 20일 (토) 오후 10:02, Yahoo Mail <spjong07@yahoo.com>님이 작성:

Dear Sir,
I herewith send you the revised paper. I would also like to thank you for editing the references in the text. We went through the whole paper (YELLOW). We replaced FAO (1993) with FAO (2003) and Stevens (2007) with Kang et al. (2015). The running title: Response of purpleback flying squid to bait color. I hope the paper could have met your requirements. Thank you.

Silvester B. Pratasik
(Corresponding author)

On Wednesday, May 17, 2023, 09:27:56 AM GMT+8, 거목문화사 <guhmok@guhmok.com> wrote:

Hello. Nice to meet you.
We are a **Guhmok publishing company** that is editing and proofreading FAS (Fisheries and Aquatic Sciences).

This month, FAS will be published.

Please, check the attached file (PDF).
Please refer to the pdf that has been marked for correction, and please indicate what you want to edit in the final edited pdf.
If you want change anything, you can change through E-mail message and PDF's memo.
If Authors have IRB/IACUC approval, please provide the institution and approval number.
ex) This research has been approved by the Institutional Animal Care and Use Committee (IACUC) of Kongju National University, Korea (KNU-IACUC-2018-xxx).

Please, let me know easily and accurately.
For example, let me know about accurate page, figure number and table number.

The basic poorfreading principle is as follows.
1. Please take a close look at the revised part and be sure to mention the part we made the wrong correction.
2. We have found the references one by one and modified them in accordance with the regulations.
 - Please confirm the revision, and if there is anything that needs to be changed, please reply by e-mail.
 - In the case of reports, old books, etc., it is difficult to confirm the accuracy of the references on the internet. So, author must confirm.
 - If you have not checked the original text and used it as a reference, please consider the changes.
 - There are many cases in which references are copied and used in other papers, and references are made to incorrect or missing references.
 - When copying a reference section of another article, many references are cited with incorrect or missing references.
3. We have edited all papers in accordance with the editorial committee guidelines, which can not be changed until approval by the editorial committee.
 - We used a single space in front of every unit mark, but there is no space in front of the %, °, and °C marks. Etc…
4. If the abbreviated words are first appeared, please write the full name and abbreviate it afterwards.
5. The abbreviation used in the table should be given to the full name at the bottom so that you can see it separately from the main text.
6. All author's department, institution (university), city and country are required.
7. The memos in PDF file are an important part, so check carefully.

Please reply by May 20, 2023, 11:00 am.

***If there are two corresponding authors, please send the revised contents into one file.**

If there are no edits, please reply with the message that you do not need to make any changes.

Thank you for your cooperation.

Best regards,
Guhmok Publising

[거목문화사] 학술지 편집/인쇄 · 홈페이지 · 논문투고시스템 · JATS XML
04549 서울시 중구 을지로 148 중앙데코플라자 609호
TEL(대표): 02-2277-3324, FAX: 02-2277-3390
Homepage: http://www.guhmok.com E-mail: guhmok@guhmok.com
웹하드: http://www.webhard.co.kr ID: guhmok PW: 22773324

1 File 784.8kB

03-FAS(Research article)_2022-0089_Silvester Benny Pratasik.pdf
785kB