Aquacultural Engineering 90 (2020) 102074

Contents lists available at ScienceDirect

Aquacultural Engineering

journal homepage: www.elsevier.com/locate/aque

Catch me if you can: How to recapture lumpfish using light as an attractant

Atle Foss[a,1], Albert K.D. Imsland[b,c,1,*], Bjørn Roth[d], Ane V. Nytrø[a,2]

[a] Akvaplan-niva, Framsenteret, 9296, Tromsø, Norway
[b] Akvaplan-niva Iceland Office, Akralind 4, 201, Kópavogur, Iceland
[c] Department of Biological Sciences, University of Bergen, High Technology Centre, 5020, Bergen, Norway
[d] Nofima, Department of Processing Technology, POB 8034, N-4068, Stavanger, Norway

ARTICLE INFO

Keywords:
Light
Fish traps
Lumpfish
Re-catch
Light spectrum
Salmon farming

ABSTRACT

The use of lumpfish in salmon farming allows the removal of sea lice all year round, without the use of chemicals or mechanical treatments. In Norway alone, around 31 million lumpfish are currently put into sea pens whereas no efficient method to re-catch these fish once they no longer are efficient salmon lice grazers (from 300 g) exists. At present, collecting lumpfish in sea-cages is a labour- and time-consuming process and, if these fish are to be harvested, an efficient method for collecting lumpfish is urgently needed. In this study, we tested coloured light as an attractant to lure lumpfish into passive traps (pods). Three small-scale pilot experiments both demonstrated the highest re-capture rate when a blue light-source was used, whereas red and yellow light gave the lowest re-capture rate. A subsequent large-scale trial failed to demonstrate significant re-catch of lumpfish. It is concluded that although blue light clearly attracted lumpfish in laboratory trials, further studies are needed in order to exploit this attribute commercially.

1. Introduction

With a rising human population and a subsequent need for sustainable protein sources, aquaculture is becoming an increasingly important industry worldwide (Little et al., 2016). Driven by large profit margins, salmonid aquaculture is responsible for approximately 7% of fish production worldwide (Aaen et al., 2015). However, the salmon farming industry faces a plethora of challenges in maintaining the welfare of their stock throughout the sea-based phase. The largest biological challenge is the caligdae ectoparasite, *Lepeoptheirus salmonis,* which can cause significant external damage resulting in secondary infections, osmoregulatory imbalance and related stress (Wootten et al., 1982). The use of cleanerfish as a biological grazing technique for sea lice removal has been a popular eradication method since 2010 (Brooker et al., 2018). The most commonly used cleanerfish in the salmon sector is lumpfish *Cyclopterus lumpus* which can target the parasite across all seasons (Imsland et al., 2014a,2018a; Eliasen et al., 2018; Powell et al., 2018).

As lumpfish has been proven to be an efficient biological delouser (Imsland et al., 2014a,c, 2018a), commercial production of lumpfish has increased rapidly and reached 30 million juveniles in 2018 in Norway (Norwegian Directorate of Fisheries, 2019), approximately 6 million in the UK (Treasurer et al., 2018), 3.5 million in Iceland (Viðar Örn Victorsson, Head of lumpfish production, Stofnfiskur, Iceland, pers. comm.), around 1 million in Canada (Mayer, 2019) and 300 thousand in Ireland (Bolton-Warberg, 2018). Imsland et al. (2016) investigated possible effects of lumpfish size on sea lice grazing efficiency and found that small lumpfish (initial size approx. 20 g, final size 240 g) have a higher overall preference to eating sea lice compared to larger conspecifics (initial size 90 g, final size 400 g). Currently the Atlantic salmon farming industry uses lumpfish up to c. 400 g. As of today, collecting lumpfish in sea-cages is a labour- and time-consuming process and, if these fish are to be harvested in a sustainable manner, an efficient method for collecting lumpfish is urgently needed.

Submersible light traps are selective live-capture devices that collect photopositive nekton including a broad range of pelagic juvenile fishes (Doherty, 1987; Meekan et al., 2000) and is now widely used within commercial fisheries (Nguyen and Winger, 2019). McLeod and Castello (2017) reviewed the use of light traps to sample marine biodiversity and found that survey of the literature of light-trap designs showed they collected at least 12 phyla of benthic and planktonic animals, and 13 orders of crustaceans. For fish it is known that they can be attracted, or otherwise affected, by artificial light (Hasegawa, 1993; Marchesan et al., 2005; Masuda et al., 2015). Recently the use of green light in

* Corresponding author at: Akvaplan-niva Iceland Office, Akralind 4, 201, Kópavogur, Iceland.
E-mail address: aki@akvaplan.niva.no (A.K.D. Imsland).
[1] Equal authorship between Foss and Imsland.
[2] Present address: Department of Biology, Norwegian University of Science and Technology, NO 7491, Trondheim, Norway.

https://doi.org/10.1016/j.aquaeng.2020.102074
Received 13 January 2020; Received in revised form 13 March 2020; Accepted 15 March 2020
Available online 16 March 2020

floating pots has been tested with success for Atlantic cod, *Gadus morhua* (Bryhn et al., 2014) where catch per unit effort (CPUE) of large (> 38 cm) cod was increased by 74 % with the use of green light inside the trap. Green light was used as previous research had shown that cod vision reacts to different wavelengths of photons with the cod primary sensitivity peak at 490 nm (blue/green light, Anthony and Hawkins, 1983). However, very little is known about the colour preference of lumpfish. Imsland and Conlon (2019) investigated preference for four different colours (white, black, green and blue) of thin plastic sheets mimicking those currently in use in lumpfish hides in sea pens (Imsland et al., 2018b) and found a clear preference to the black colour. The observed variation in colour preference is promising in relation to developing some kind of colour attractant in order to develop a collecting method for lumpfish in sea pens.

The aim of the present study was to develop efficient recapture methods for lumpfish in sea pens using colour as an attractant.

2. Materials and methods

2.1. Experimental fish

The lumpfish were produced from fertilised eggs from Senja Akvakultursenter AS, Senja, Troms County, Norway. The eggs were incubated at 9–10 °C and the juveniles were first-fed with Gemma Micro (150–500 µm, Skretting, Norway). After 30 days, the feed was switched to 500–800 µm dry feed (Gemma Wean Diamond, Skretting, Norway). On 25 November 2015 when the juveniles were around 10 g the fish were vaccinated with ALPHA JECT Marin micro 5 (Pharmaq AS, Oslo, Norway). From November 2015 to April 2016 the juveniles were fed a high protein (56.5 %), low fat (15.6 %) marine feed (Biomar lumpfish grower, 2 mm, Biomar, Trondheim, Norway). A 50 % mixture of 1.5 mm and 2 mm pellets was used during this period.

2.2. Colour attractant trial – small scale test

Colour preferences in lumpfish were investigated in group of 222 juvenile lumpfish with mean ± SE weight of 31.4 ± 1.4 g at Akvaplan-niva AS research station at Kraknes, Troms county in April 2016. The fish were reared under a 16 h light: 8 h of darkness (LD16:8) photoperiod during the trials. Six tanks (1500 l) were used, each containing 37 juvenile lumpfish. A modified crab pod (OK MARINE, Kristiansand, Norway, https://webshop.okmarine.no/krepseteine-med-innerkalv-sort, Fig. 1) was used as trap. The pod had dimensions 70 × 40 × 27 cm, outer frame of galvanized steel dipped in PVC and covered with 30 mm mesh polyethylene netting. There were two entrances and lights inside was placed in the tank in total darkness for 1 h and the fish in each tank exposed to the light attractant test once a day. The trap was covered with PVC-tarpaulin to prevent light from escaping the trap outside the entrances, and a small camera was mounted near the entrance to monitor the timing of the entry of the fish collected. All light sources were tested in two (glowsticks) and four (LED) replicates. The rearing facility was kept totally dark during the colour attractant trial. After one hour, the pod was removed from the tank and the lumpfish trapped inside were counted and released back into the tank. Three small-scale experiments tested different light sources and colours.

In the first small-scale experiment, four different coloured glowsticks (www.Glowshop.no) were tested: blue, green, red and yellow. Each test was performed for 1 h and repeated twice in two replicate tanks. Only one colour was tested each day. The sequence of the colours was randomized.

In the second experiment, four different colours of LED light (RGB LED Flood Underwater Spot10W 12 V) were tested: blue, green, purple and white. The wavelengths of the tested LED lights were 470, 523 and 627 nm for the blue, green and red light, respectively. Each test lasted 1 h and was performed in four replicate tanks and repeated twice with one colour tested each day and the sequence of the colour tests randomized.

In the third small-scale test different types of the preferred colour in the first two small-scale trials was tested using different types of light sources (glowstick or LED-light) and with or without flashing/blinking bait (Glowbite Fishing Innovation) placed within the experimental pod. Each test lasted 1 h and was performed in four replicate tanks and repeated twice with one colour and flashing combination tested each day and the sequence of the colour combination tests randomized.

Fig. 1. A modified crab pot used for small-scale testing in tanks.

2.3. Colour attractant trial – large-scale pilot test

Based on the preferred colour found in the two first small-scale tests a third pilot experiment was performed with blue light only. A prototype version of a pod (Fig. 2) was developed (OK MARINE, Kristiansand, Norway, 110 × 40 × 27 cm) and tested in two full size seacages commercial Atlantic salmon sea farm at 69.80 °N, 19.41 °E (Lerøy Aurora, Troms county, Norway). Each sea-cage (160 m circumference, 58900 m^3 volume contained around 125,000 juvenile salmon with a mean weight of 800 g and approximately 10,000 lumpfish in the size range 30 − 80 g. The pod was covered with a blue PVC-tarpaulin and blue three LED-lights (10 W) were installed inside the pod. A trial was performed during nighttime on 29 November 2016. In each cage the pod was lowered with a crane near a lumpfish hide (approx. 2 − 3 m from the cage ring, Fig. 2) inside the sea cage at a depth of 4 − 5 m and kept there for one hour and the pod then raised, lumpfish inside counted, released and the pot lowered empty again. The trial was repeated three times during the night.

2.4. Statistical analyses

A Chi squared test (Zar, 1984) was used to determine statistical

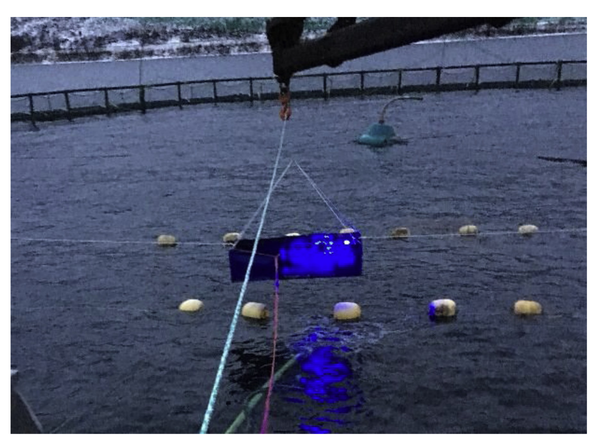

Fig. 2. Test of re-capture of lumpfish in commercial facilities. Prototype pod used to catch lumpfish in the sea-pen during night.

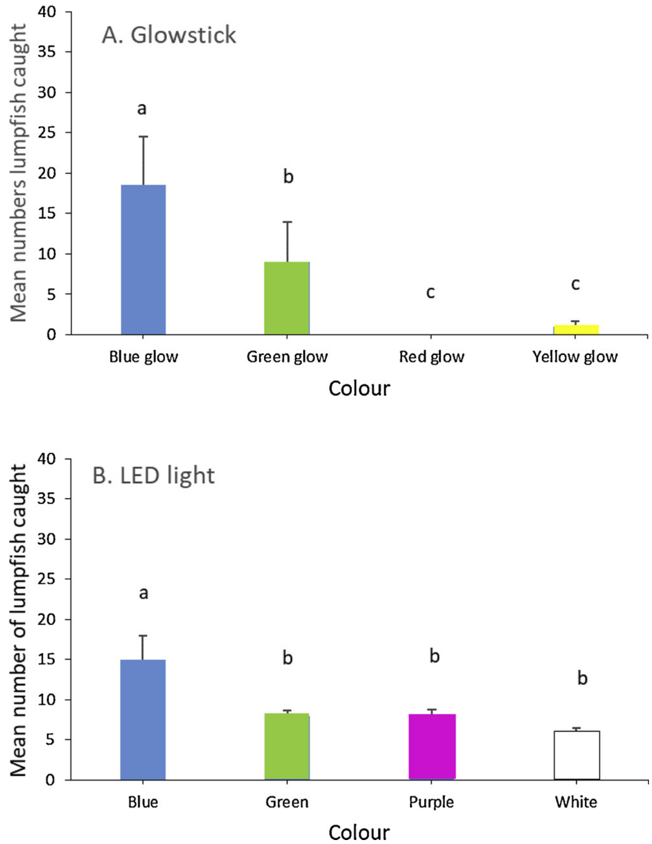

Fig. 3. Pilot experiments using glowsticks (A) and LED-lights (B) with different colours to attract juvenile lumpfish. Data are shown as mean (SE). Different letters indicate significant differences (χ^2 test, $P < 0.05$).

significance across the mean data points in both small- and large-scale trials:

$$x^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

where the O_i is the observed frequency of colour i and E_i is the expected value of colour i. For the first (glowsticks) and third (glowsticks and LED with or without blink) small-scale trial the colour that gave the strongest response in the initial tests was chosen as the expected value in the chi square tests. In the second (LED) small-scale test white was used as the expected value in the test. Significant, $P < 0.05$, values were found at ${\chi_1}^2 > 3.84$.

3. Results

3.1. Colour attractant trial – small-scale trial

The first two pilot experiments both demonstrated the highest recapture rate when a blue light-source was used (${\chi_1}^2 > 6.4$, $P < 0.01$, Fig. 3), whereas red and yellow light gave the lowest re-capture rates (Fig. 3A). Based on results from the first two pilot experiments, blue light was chosen for further testing where colour attraction was compared between LED-light and glowstick both with and without an additional blinking angle present (Fig. 4). When testing different blue light sources it was evident that LED-lights outperformed glowsticks (${\chi_1}^2 > 4.2$, $P < 0.05$, Fig. 4), whereas additional blinking angling baits had little effect (${\chi_1}^2 < 0.8$, $P > 0.35$, Fig. 4). Re-capture rates of more than 70 % after one hour were obtained with LED-lights both with or without the blinking angling (Fig. 4).

3.2. Colour attractant trial – large-scale trial

Based on findings from the small-scale studies in tanks, a modified pod with three blue LED-lights within the pod was designed (Fig. 2) and tested in two commercial size salmon sea cages with lumpfish at 6% density present. A total of three attempts were made in each cage with minimal success as only three lumpfish, or less, were caught in each attempt. The mean weight (± SE) of the fish caught was 66.4 (12.4) g.

4. Discussion

There are only a few published papers describing the ability of lumpfish to distinguish between colours (Ahmad et al., 2019; Imsland and Conlon, 2019) highlighting the novelty of this particular trial. However, male lumpfish exhibit bright orange, purple, and red colouration during the spawning season (Davenport and Thorsteinsson, 1989), which suggests an ability for lumpfish to detect colour. Post--hatch lumpfish are visually guided predators and feed on shrimp, crustaceans, jellyfish, worms and other fish (Ingólfsson and Kristjánsson, 2002; Ahmad el al., 2019). Lumpfish are known mainly as demersal bottom-dwelling fish but can also exist semi-pelagically and Scott and Scott (1988) discuss observations that provide some evidence that lumpfish can dwell in the upper levels of the mesopelagic zone (200–1000 m depth), where light levels are low. One of the main nutritional sources of the pelagic juvenile lumpfish in the Barents Sea is the glass jellyfish, *Beroe cucumis* (Welch et al., 2005). These jellyfish are bioluminescent and iridescent displaying blue bioluminescent light. Coincidentally, the species area of distribution 0 – 1000 m (Angel et al., 1982) matches that of the adult lumpfish down to 1000 m depth (Scott and Scott, 1988).

Recently Ahmad et al. (2019) published the first systematic analysis of the anatomy, histology, imaging findings and molecular expression patterns of the eyes of developing cultured lumpfish. Several novel features were found in the eye and retina of cultured lumpfish including novel imaging findings and protein expression characteristics. As in the study of Imsland and Conlon (2019); Ahmad et al. (2019) reported that lumpfish often adhere to surface structures with an eye close to or protruding from the surface of the water. Ahmad et al. (2019) argue that this behaviour suggests some level of out-of-water visual interest and capability for seeing features in a vertical plane. It was noted that cultured lumpfish will often move through the water or remain stationary with their heads slightly vertical in the water rather than horizontally like other fish. These behaviour patterns prompt questions about whether lumpfish might utilise their vision, including the novel structures in the ventral portions of their retinas (Ahmad et al., 2019) for perception of vertical or other lines of sight in their environments. In the present study the preference of blue glowsticks might indicate the detection, and preference, of a visual stimulus in the water column. It should also be taken into account that colour changes with water depth due to the absorption of the different wavelengths (Kröger, 2008). However, lumpfish habitats are most commonly placed between 2 – 10 m in salmon pens (Imsland et al., 2018a,b) and therefore lumpfish could still be visually stimulated in this depth range.

Capture and re-use of lumpfish is a necessity for the Atlantic salmon farming industry if cleanerfish are to be used in the future as a sustainable lice treating method. Accordingly, it is necessary to develop a holistic approach for catching, re-use and further exploitation of lumpfish as a market product (e.g. for human consumption). The present small-scale experiments demonstrated that blue light was an effective attractant to juvenile lumpfish. Using blue LED-light resulted in almost 75 % of the lumpfish in the tank swimming into the trap and, out of these, more than 90 % of the fish caught swam into the trap within the first 20 min. Red and yellow colour resulted in close to zero catch, whereas green, purple and white lights resulted in intermediate catches. A commercial prototype trap was tested in a cage facility at night. The trap was placed close to the cleanerfish-shelters (artificial seaweed) and

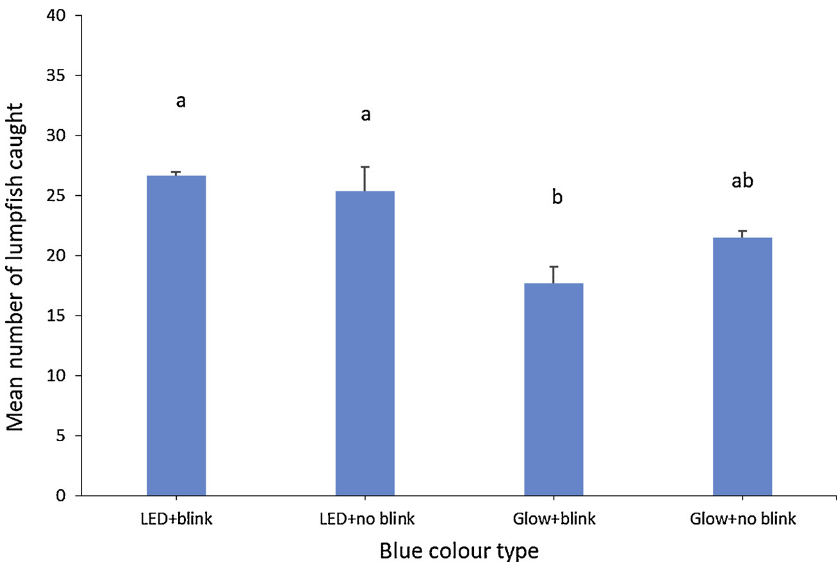

Fig. 4. Pilot experiment using blue glowsticks and LED-lights with/without blinking lights in pod to attract juvenile lumpfish. Data are shown as mean (SE). Different letters indicate significant differences (χ^2 test, $P < 0.05$). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

left for one hour, but very few fish were caught. The procedure was repeated at different locations in the sea-cages, but very poor catches were obtained each time. It is difficult to point out one single reason for this discrepancy, but there are some possible reasons we would like to point out. It is possible that the time interval was to short to successfully catch lumpfish. In their light trap experiments with Atlantic cod Bryhn et al. (2014) used a much longer time interval (1–19 days). Similar size intervals of lumpfish were tested in both small- and large-scale testing so different size of lumpfish did not cause the differences between the tests. The small-scale test was performed in spring (April) whereas the large-scale test was done during late autumn (November) so differences in light conditions and/or photoperiod may have contributed to the difference seen. Lumpfish are active during nighttime (Leclercq et al., 2018) and spend around 60 % of their time eating or searching for food (Imsland et al., 2014b) so it is unlikely that the lumpfish were inactive during the test in the sea cages. In the sea-pen the lumpfish adhere to artificial substrate in special lumpfish shelters (Imsland et al., 2018b) so the light signal may possible have been too weak for the fish to perceive or not attractive enough for the fish to leave their shelter. The large-scale trial was performed during the night and earlier results have shown that lumpfish spend the majority of daylight hours foraging and utilise their shelter more frequently during nocturnal hours (Imsland et al., 2014a,b, Leclercq et al., 2018). Ambient temperatures at the Kraknes research station in April (~ 5 °C, Imsland et al., 2019) are similar to that found at the large-scale facility in November (~6 °C, Imsland et al., 2018a) so this is unlikely to contribute to the different recapture findings. Overall it is difficult to pinpoint a single reason for the lack of response of lumpfish in the large-scale testing.

5. Conclusion

In conclusion, blue light effectively attracted juvenile lumpfish in a small-scale study in a tank, but not in a sea-cage. Future work should focus on developing an efficient method for collecting cleanerfish in commercial facilities as the intense rise in use of lumpfish as cleanerfish calls for development of lenient recapture methods. There is also a need to expand the size range investigated up to the whole commercial size range used currently (c. 20 − 400 g).

CRediT authorship contribution statement

Atle Foss: Conceptualization, Methodology, Investigation, Writing - review & editing, Writing - original draft, Project administration. **Albert K.D. Imsland:** Data curation, Project administration, Writing - original draft, Writing - review & editing. **Bjørn Roth:** Conceptualization, Methodology. **Ane V. Nytrø:** Conceptualization, Methodology, Investigation, Validation.

Declaration of Competing Interest

There is no conflict of interest in relation of the findings of the present manuscript.

Acknowledgements

The study was financed by the Norwegian Seafood Fund (FHF, 901235). We would like to thank the staff at Kraknes Research Station for their assistance during the trials.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.aquaeng.2020.102074.

References

Aaen, S.M., Helgesen, K.O., Bakke, M.J., Kaur, K., Horsberg, T.E., 2015. Drug resistance in sea lice: a threat to salmonid aquaculture. Trends Parasitol. 31, 72–81.
Ahmad, R., Paradis, H., Boyce, D., McDonald, J., Gendron, R.L., 2019. Novel characteristics of the cultured Lumpfish *Cyclopterus lumpus* eye during post-hatch larval and juvenile developmental stages. J. Fish Biol. 94, 297–312.
Angel, M.V., Hargreaves, P., Kirkpatrick, P., Domanski, P., 1982. Low variability in planktonic and micronektonic populations at 1,000 m depth in the vicinity of 42 N, 17 W; evidence against diel migratory behavior in the majority of species. Biol. Oceanogr. 1, 287–319.
Anthony, P.D., Hawkins, A.D., 1983. Spectral sensitivity of the cod *Gadus morhua* L. Mar. Behav. Physiol. 10, 145–166.
Bolton-Warberg, M., 2018. An overview of cleaner fish use in Ireland. J. Fish Dis. 41, 935–939.
Brooker, A.J., Papadopoulou, A., Gutierrez, C., 2018. Sustainable production and use of cleaner fish for the biological control of sea lice: recent advances and current challenges. Vet. Rec. 183 383–383.
Bryhn, A.C., Königson, S.J., Lunneryd, S.G., Bergenius, M.A.J., 2014. Green lamps as visual stimuli affect the catch efficiency of floating cod (*Gadus morhua*) pots in the Baltic Sea. Fish. Res. 157, 187–192.
Davenport, J., Thorsteinsson, V., 1989. Observations on the colours of lumpsuckers, *Cyclopterus lumpus*. J. Fish Biol. 35, 829–838.
Doherty, P.J., 1987. Light-traps: selective but useful devices for quantifying the relative abundance of larval fishes. Bull. Mar. Sci. 41, 423–431.
Eliasen, K., Danielsen, E., Johannesen, Á., Joensen, L.L., Patursson, E.J., 2018. The cleaning efficacy of lumpfish (*Cyclopterus lumpus* L.) in Faroese salmon (*Salmo salar* L.) farming pens in relation to lumpfish size and seasonality. Aquaculture 488, 61–65.
Hasegawa, E., 1993. History, development and present condition of fishing with light.

Bull. Fac. Bioresour. Mie Univ. 10, 131–140 (in Japanese with English abstract).
Imsland, A.K.D., Conlon, H., 2019. Money for nothing: the possible use of recycled fish farm material as habitat for lumpfish. J. Aquac. Eng. Fish. Res. 87, 102015.
Imsland, A.K., Reynolds, P., Eliassen, G., Hangstad, T.A., Foss, A., Vikingstad, E., Elvegård, T.A., 2014a. The use of lumpfish (*Cyclopterus lumpus* L.) to control sea lice (*Lepeophtheirus salmonis* Krøyer) infestations in intensively farmed Atlantic salmon (*Salmo salar* L.). Aquaculture 425-426, 18–23.
Imsland, A.K., Reynolds, P., Eliassen, G., Hangstad, T.A., Nytrø, A.V., Foss, A., Vikingstad, E., Elvegård, T.A., 2014b. Notes on behaviour of lumpfish in sea pens with and without Atlantic salmon. J. Ethol. 32, 117–122.
Imsland, A.K., Reynolds, P., Eliassen, G., Hangstad, T.A., Nytrø, A.V., Foss, A., Vikingstad, E., Elvegård, T.A., 2014c. Assessment of growth and sea lice infection levels in Atlantic salmon stocked in small-scale cages with lumpfish. Aquaculture 433, 137–142.
Imsland, A.K., Reynolds, P., Nytrø, A.V., Eliassen, G., Hangstad, T.A., Jónsdóttir, Ó.D.B., Emaus, P.A., Elvegård, T.A., Lemmens, S.C.A., Rydland, R., Jonassen, T.M., 2016. Effects of lumpfish size on foraging behaviour and co-existence with sea lice infected Atlantic salmon in sea cages. Aquaculture 465, 19–27.
Imsland, A.K., Hanssen, A., Reynolds, P., Nytrø, A.V., Jonassen, T.M., Hangstad, T.A., Elvegård, T.A., Urskog, T.C., Mikalsen, B., 2018a. It works! Lumpfish can significantly lower sea lice infections in large scale salmon farming. Biol. Open 7, 9. https://doi.org/10.1242/bio.036301. bio036301.
Imsland, A.K., Reynolds, P., Eliassen, G., Berg-Hansen, L., Hangstad, T.A., Elvegård, T.A., Urskog, T.C., Mikalsen, B., 2018b. Assessment of artificial substrates for lumpfish: effect of material thickness and water current speed. Aquac. Int. 26, 1469–1479.
Ingólfsson, A., Kristjánsson, B.K., 2002. Diet of juvenile lumpsucker (*Cyclopterus lumpus*) in floating seaweed: effect of ontogeny and prey availability. Copeia 2, 472–476.
Kröger, R., 2008. The physics of light in air and water. In: Thewissen, J.G.M., Nummela, S. (Eds.), Sensory Evolution on the Threshold – Adaptations in Secondarily Aquatic Vertebrates. University of California Press, pp. 113–119.
Leclercq, E., Zerafa, B., Brooker, A.J., Davie, A., Migaud, H., 2018. Application of passive-acoustic telemetry to explore the behaviour of ballan wrasse (*Labrus bergylta*) and lumpfish (*Cyclopterus lumpus*) in commercial Scottish salmon sea-pens. Aquaculture 495, 1–12.
Little, D.C., Newton, R.W., Beveridge, M.C.M., 2016. Aquaculture: a rapidly growing and significant source of sustainable food? status, transitions and potential. Proc. Nutr. Soc. 75, 274–286.
Marchesan, M., Spoto, M., Verginella, L., Ferrero, E.A., 2005. Behavioural effects of artificial light on fish species of commercial interest. Fish. Res. 73, 171–185.
Masuda, D., Maeda, M., Kai, S., Sasamoto, Y., Yanagino, Y., Furukawa, K., Matsushita, Y., 2015. Fish behaviour around a trap-net with the leader-net lit by a low-power underwater lamp. Nippon Suisan Gakkai Shi 81, 10–16 (in Japanese with English abstract).
Mayer, L., 2019. Cleaner-fish technology now ready for commercialization. Aquac. North Am. 10 (5), 21.
McLeod, L.E., Costello, M.J., 2017. Light traps for sampling marine biodiversity. Helgol. Mar. Res. 71, 2–8.
Meekan, M.G., Doherty, P.J., White, L.J., 2000. Recapture experiments show the low sampling efficiency of light traps. Bull. Mar. Sci. 67, 875–885.
Nguyen, K.Q., Winger, P.D., 2019. Artificial lights in commercial industrialized fishing applications: a review. Rev. Fish. Sci. Aquac. 27, 106–126.
Norwegian Directorate for Fisheries, 2019. https://www.fiskeridir.no/English/Aquaculture/Statistics/Cleanerfish-Lumpfish-and-Wrasse.
Powell, A., Treasurer, J.W., Pooley, C.L., Keay, A.J., Lloyd, R., Imsland, A.K., Garcia de Leaniz, C., 2018. Cleaner fish for sea-lice control in salmon farming: challenges and opportunities using lumpfish. Rev. Aquac. 10, 683–702.
Scott, W.B., Scott, M.G., 1988. Atlantic fishes of Canada. Can. Bull. Fish Aquat. Sci. 2019, 518–519.
Treasurer, J., Prickett, R., Zietz, M., Hempleman, C., Garcia De Leaniz, C., 2018. Cleaner fish rearing and deployment in the UK. In: Treasurer, J. (Ed.), Cleaner Fish Biology and Aquaculture Applications. 5M Publishing Sheffield, UK, pp. 370–385.
Welch, V.L., Vigneron, J.P., Parker, A.R., 2005. The cause of colouration in the ctenophore *Beroe cucumis*. Current Biol. 15, R985–R986.
Wootten, R., Smith, J.W., Needham, E.A., 1982. Aspects of the biology of the parasitic copepods lepeophtheirus salmonis and caligus elongatus on farmed salmonids, and their treatment. Proc. Royal Soc. Biol. Sci. 81, 185–197.
Zar, J.H., 1984. Biostatistical Analysis, 2nd edition. Prentice-Hall, Inc., Englewood Cliffs, N.J 718 pp.