Fisheries and Oceans Canada
Pêches et Océans Canada

Aquaculture Collaborative Research and Development Program (ACRDP) Fact Sheet

Issue 22
December, 2013

Ecological effects of blue LED lights used at marine finfish aquaculture sites in British Columbia

Summary

The use of artificial lighting within finfish aquaculture operations is a common technique used to delay sexual maturation and produce larger fish. Currently, finfish growers in British Columbia are interested in exploring the use of blue light emitting diode (LED) lights. These blue LED lights are more efficient, use less energy and last longer than the traditionally used white metal halide lights, making them an attractive, economical choice. However, artificial lighting may affect both the diversity and abundance of the native organisms surrounding an aquaculture site, and this study evaluated these potential effects. The use of blue LED lights at an experimental site at night was found to attract fish and zooplankton, when compared to unlit controls. No statistical difference was observed for phytoplankton abundance (in the absence of blooms) or the settlement of benthic invertebrates between blue LED lights and controls. A commercial finfish site was also equipped with blue LED lights to determine their effects on fish maturation, growth and sea lice counts in comparison to a site equipped with traditional white halide lights. There was no statistical difference in sea lice counts between farm sites equipped with blue LED lights or white halide lights, but direct comparisons were difficult. The results of this project have led to an increased understanding of the effects of blue LED lights on the native biota, but continued research is necessary in order to determine the effects and implications of blue LED lights directly at an aquaculture site. This information will allow both industry and Fisheries and Oceans Canada (DFO) to continue to support the sustainable development of finfish operations in British Columbia, and better manage the intricate relationship between aquaculture and the environment.

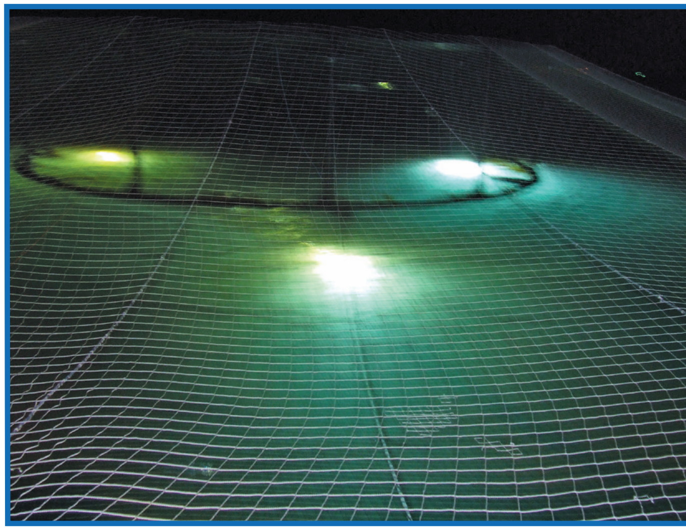

Figure 1. Artificial night lighting at an aquaculture site

The Aquaculture Collaborative Research and Development Program (ACRDP) is a Fisheries and Oceans Canada (DFO) initiative to increase the level of collaborative research and development activity between the aquaculture industry and DFO. Projects under ACRDP seek to improve aquaculture environmental performance and support optimal fish health.

Introduction

Artificial night lighting at finfish sites (Figure 1) is a common technique used by the aquaculture industry. By extending lit hours, artificial lighting can effectively delay sexual maturation, allowing the fish to direct its energy towards growth. This gives the industry the means to produce larger fish, with very little additional effort.

In British Columbia, aquaculture operations are exploring the use of blue (450 nm wavelength) light emitting diodes (LEDs) as an alternative to the traditional white metal halide lighting currently in use. Light in this blue-green spectrum is more efficient for use in seawater than white light, as these wavelengths have a higher energy content and will illuminate over greater distances. These lights also have the potential to optimize growth as they can be tuned to certain wavelengths to make the emitted light more species-specific.

Economically, LED lights draw less energy, are more efficient than white halide lights, and have a longer lifespan, all of which could provide significant cost savings. However, the effect of blue LED lights on native biota has yet to be determined. An alteration in light conditions can be a source of stress for certain species, while attracting others. There is concern that this could change the diversity and abundances of native biota in the local area.

This research project evaluated the ecological effects of blue LED lights at night relative to unlit controls on plankton (phytoplankton and zooplankton), small and juvenile fish, and on the settlement of benthic invertebrates. It also evaluated the efficacy of blue LED lights to delay sexual maturation and promote growth, and examined the effect on sea lice loads at a commercial salmon aquaculture site.

Methods

Six Idema underwater lights, model Blue LED 100W by AKVASmart (AKVA Group™, Bryne, Norway) were suspended from a floating saltwater dock (Figure 2) at an experimental site at Fisheries and Ocean Canada's (DFO) Centre for Aquaculture and Environmental Research (CAER) in West Vancouver, British Columbia.

Each light source consisted of blue light emitting diodes (LEDs) arranged in rows and encased in a borosilicate sheath filled with oil to regulate temperature. Each of the six blue LED light units were suspended from the dock railing with 3/8 inch galvanized chains. A 2.3 to 4.5 kg lead weight was attached using chain to the end of each unit to keep the apparatus upright and stable in the water column (Figure 3).

The period of illumination was from 15 minutes before sunset to 15 minutes post sunrise, with adjustments to the photoperiod made every two weeks. Of the six lights, only three were on at any one time, and the treatments alternated light position. Lights were spaced approximately 10 m apart, which was determined to be further than the penetration of the light through the water. This ensured that lit treatments did not interfere with control treatments. Sampling took place every two weeks from October 2011 to May 2012.

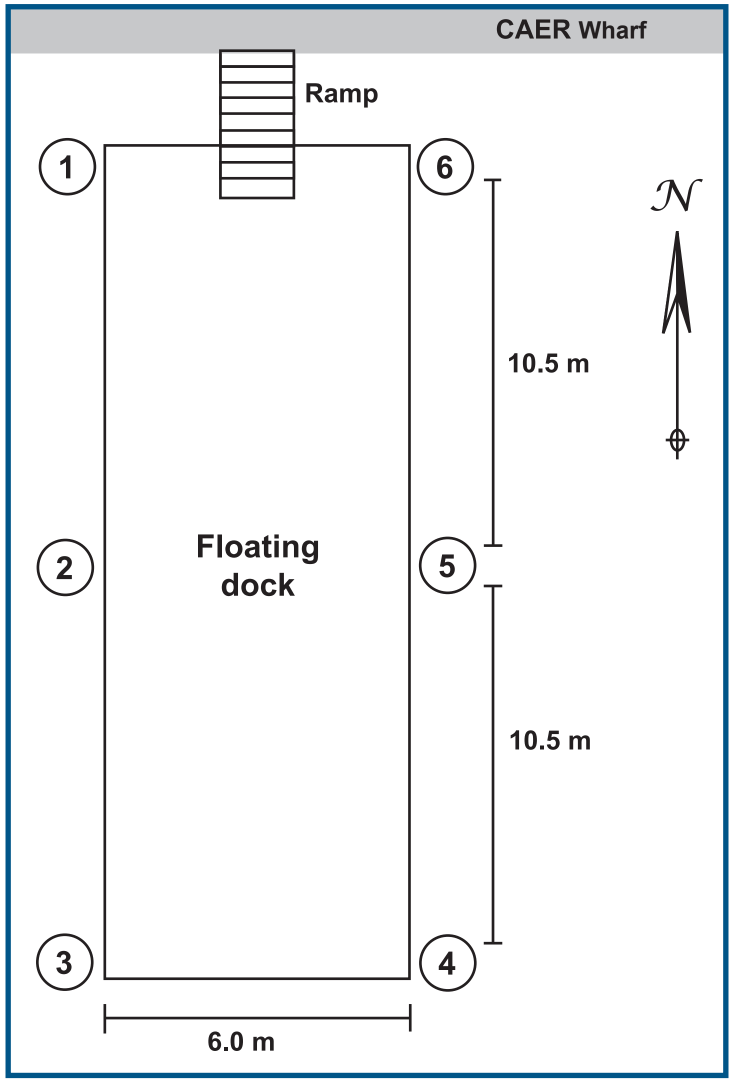

Figure 2. Experimental site setup, showing placement of the light units.

Water turbidity and light intensity

Water column turbidity (water clarity) was measured using a Secchi disk at the dock at approximately noon on each sampling day, and was used to calculate how far the natural daylight penetrated the water. At night, the light intensity (the distance the light penetrated the water) of the blue LED lights was measured as photosynthetically active radiation (PAR) using a LiCor Quantum Spherical Sensor (light sensor) and LiCor 1400 Datalogger. Measurements were taken in 1 m increments horizontally away from the light (with 0 m measured with the sensor touching the middle of the light), up to a distance of 10 m for both lit and unlit treatments. Ten replicates of the light readings were taken at each distance.

Plankton (phytoplankton and zooplankton) sampling

Plankton (phytoplankton and zooplankton) were sampled at night, approximately 4 – 7 hours after the lights were turned on. A vertical plankton tow was conducted directly beside each light using a 100 micron plankton net that was 150 cm in length and had a 50 cm diameter opening. Plankton samples were preserved in a 70% ethanol solution and sent to EcoAnalysts Inc. (Moscow, Idaho, USA) where zooplankton and phytoplankton were identified and counted.

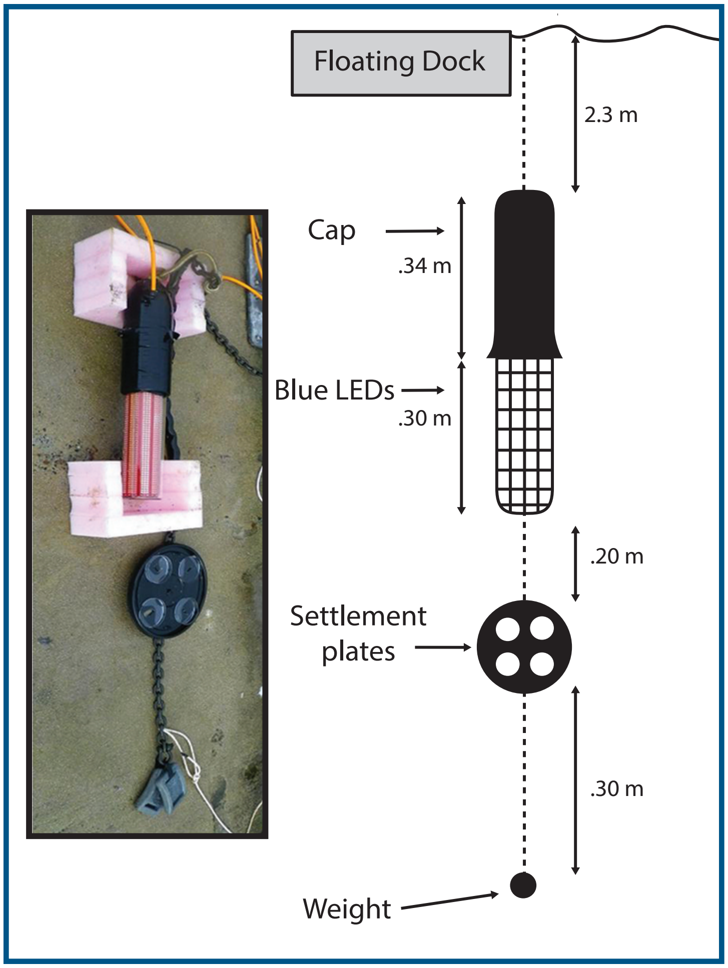

Figure 3. **Blue LED units attached to chain with weights to keep vertical.**

Fish sampling

Minnow traps (26 cm by 26 cm by 44 cm) consisting of 0.3 cm square mesh were used to sample small and juvenile fish around the lights. Each trap was baited with fish pellets, suspended at the same depth as the light, and weighted to stay upright in the water column. One trap was deployed at each of the six lights 30 minutes before sunset, and retrieved 15 – 30 minutes before sunrise. The contents of each trap were identified, counted, photographed and released.

Settlement of benthic invertebrates

Four settlement plates were hung from the bottom of each light (Figure 3). Every three months, one settlement plate from each light unit was removed for sampling. The plates were photographed on both a white and black background and the species colonizing the plates were identified. All images were later analyzed for percent coverage of organisms using ImageJ software.

Effect of blue LED on salmon maturity, growth and sea lice loads

Salmon smolts (of similar genetic background) were raised to harvest in sea pens at a commercial aquaculture site. The fish were exposed to white metal halide lights for an initial growth period, after which they were split into two groups. Half of the fish continued to be exposed to the white halide light (Culloden site), and the other half were transferred to an identical pen on another site (Ahlstrom site) and exposed to blue LED lights (Figure 4). Each pen was 30.5 m square, with a light suspended at a depth of 8 m in the center of each 15.25 m square quadrant, so that each pen had four lights spaced evenly in a grid formation. Harvest began on July 7, 2011 at Culloden and August 4, 2011 at Ahlstrom, and alternated between the sites until January 31, 2012. Sexual maturity, weight and sea lice load of each fish was recorded.

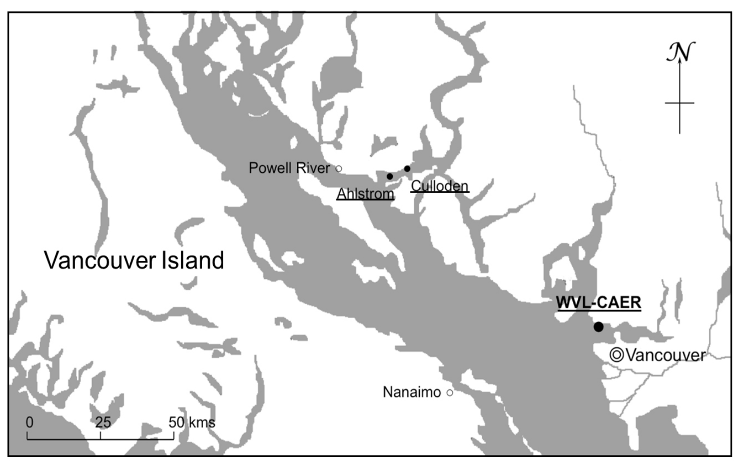

Figure 4. **Map showing relative locations of experimental site at the Centre for Aquaculture and Environmental Research (WVL-CAER), and commercial farm sites. Ahlstrom is the farm site with blue LED lights, and Culloden is the farm site which used white metal halide lights.**

Results

Water turbidity and light intensity

Turbidity was significantly higher during the spring, than either autumn or winter, which did not differ significantly. A trend of reduced light penetration through the water column was observed during winter and spring but the differences between seasons were not significant. Light intensity (as measured by photosynthetically active radiation) was reduced to less than 90% of the initial intensity within 2 metres from the light source, regardless of season or turbidity.

Plankton (phytoplankton and zooplankton) sampling

Light had no significant effect on phytoplankton abundances except during seasonal blooms, when substantially more phytoplankton was collected around the lit treatments than the unlit treatments.

Significantly more zooplankton was caught around lit LED lights, than unlit controls. Zooplankton samples consisted almost exclusively of crustaceans, of which 95% were identified as copepods.

Fish sampling

There was an observable seasonal effect on both fish diversity and abundance at the sample site. Fish were virtually non-existent around unlit control lights, while the blue LED lights attracted significantly more fish, predominantly sticklebacks. During one unique sampling event 36 young Pink Salmon were observed at a lit treatment.

Settlement of benthic invertebrates

There was no significant difference in settlement of benthic invertebrates between lit and unlit treatments. Settling plates during all sampling periods and in both treatments exhibited low bio-diversity and were colonized almost solely by barnacles and diatoms. A few solitary mussels were found on the settlement plates in May.

Effect of blue LED on salmon maturity, growth and sea lice loads

On the site equipped with blue LED lights it was observed that for a large percentage of the fish, maturation was not delayed as desired. As the fish were not harvested from the two sites at the same time or during overlapping periods, a direct comparison between light treatments is difficult. There was no statistical difference in sea lice counts between the Ahlstrom site (blue LEDs) and the Culloden site (white metal halide lights).

Conclusions

This project was successful in increasing knowledge on the effect of blue LED lights on the native biota in British Columbia. The use of blue LED lights at night can be expected to attract zooplankton and some fish species; the effects on the settlement of benthic invertebrates and phytoplankton (in the absence of blooms) appear to be insignificant. In this study, no comparison was made between the attraction of species to the raft/light structure during daylight hours, or to evaluate the duration of attraction of species to the light sources at night. Future studies could address these questions.

As part of this study took place away from aquaculture operations, future research must further examine the effects of blue LED lights directly at a finfish aquaculture site. This will allow a better understanding of the penetration of the blue LED light outside of the fish cage and any potential effects on the native organisms. Further studies at sea pen sites will be needed to examine the full impact of blue LED lights on fish maturation, growth and sea lice loads.

The information gained through this project will allow both the industry and Fisheries and Oceans Canada (DFO) to continue to support the sustainable development of finfish operations in British Columbia, and better manage the intricate relationship between aquaculture and the environment.

This ACRDP project (P-11-01-001) was a collaborative effort between Fisheries and Oceans Canada (DFO) and Grieg Seafood. The lead scientist on this project, Dr. Hannah Stewart can be contacted at :
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For further information on this and other ACRDP projects, visit: http://www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

Published by: Fisheries and Oceans Canada, Aquaculture, Biotechnology and Aquatic Animal Health Science Branch, Ottawa, Ontario K1A 0E6

DFO/2013-1915
Cat No.: Fs48-2/22-2014E-PDF
ISSN: 1919-6806 (Print)
ISSN: 1919-6814 (Online)
ISBN: 978-1-100-22985-0

French version and alternative formats available through: **http://www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/ index-fra.html**