Deep Water Renewal of Loch Etive

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Introduction

Loch Etive is a coastal sea loch on the west coast of Scotland (Figure 1). The loch was formed over the last 2 million years as glaciers retreated from Scotland and is classified as a glacially over-deepened trough. Due to its glacial formation it is comprised of two basins: the upper basin and lower basin. The Bonawe Sill is located near the middle of the loch and signals the start of the upper basin. Due to high inputs of freshwater runoff from rainfall, the upper loch experiences periods of high stratification. When rainfall levels decrease, sea water can flow over the Bonawe Sill and replenish the nutrient poor upper basin. This event is called a flushing event and occurs approximately every 16 months (Figure 2). During periods of stratification, deep water in the upper basin can become anoxic which has numerous negative effects on the ecosystem of the loch.

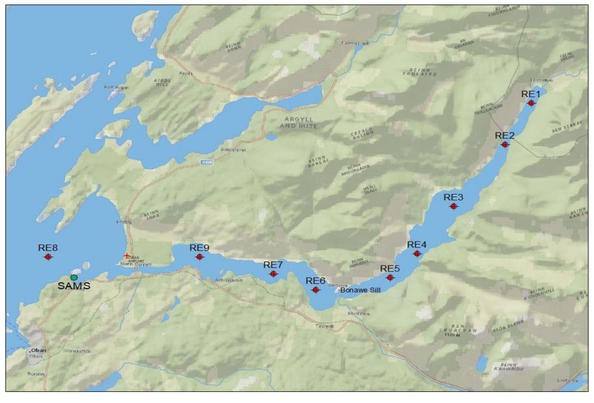
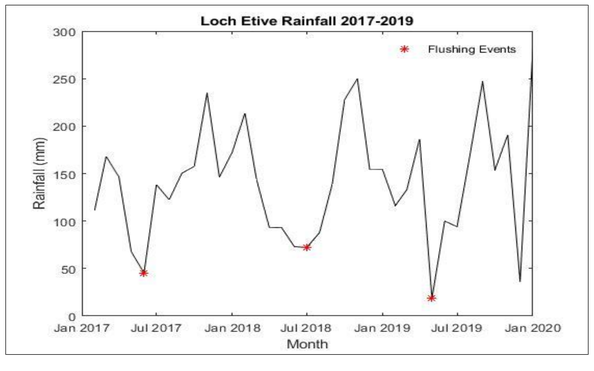


Figure 1: Loch Etive, with the locations of sampling stations RE1-RE9.

Figure 2: Rainfall measured at SAMS, with renewal events marked for the past three years.



Materials/Methods

Data collection occurred over the course of two sets of research cruises on Loch Etive, one in March by SAMS researchers, and one in May by CCU students. At each marked location (Fig. 1) a CTD and rosette of Niskin bottles was deployed, and water was collected for every ten meters. After retrieving the device, water samples were collected from each bottle with location and bottle number labeled. These samples were then used to analyze phosphate levels and chlorophyll concentration using a spectrophotometer in the SAMS lab. Data were then processed in Matlab where contour plots were created showing nutrients and physical properties in the upper basin before and after the flushing event.

Results

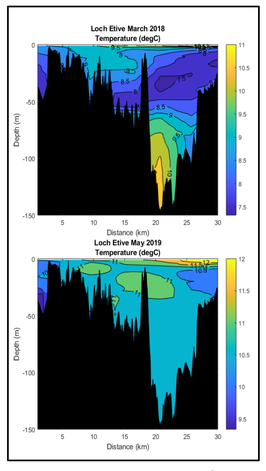


Figure 3: Temperature with depth profiles for Loch Etive for March 2018 (top graph) and May 2019 (bottom graph).

The temperature data collected in March 2018 showed surface water was between 9.5-10.5°C (Figure 3). The data also provided evidence of isolated, warm deep water in the upper basin of Loch Etive from the previous year's renewal event. The temperature data collected in May 2019 showed a very different depth profile. The water in the loch was 11°C for all depths below 20 meters. This shows that a renewal event has occurred, flushing out the previous year's bottom water.

In March 2018, the surface salinity decreased significantly moving up the loch because of river input of fresh water (Figure 4). Additionally, isohalines across the basin were tilted forming a salt wedge indicating high stratification in the upper loch. In May 2019, the isohalines were almost vertical in the upper basin, indicating a well-mixed system. This is also evidence that a renewal event occurred between the cruises.

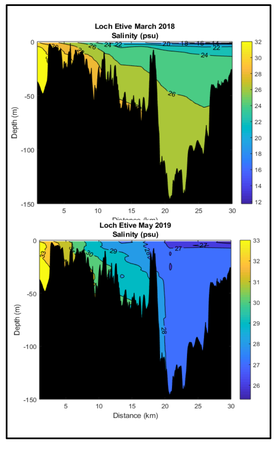


Figure 4: Salinity with depth profiles for Loch Etive for March 2018 (top graph) and May 2019 (bottom graph).

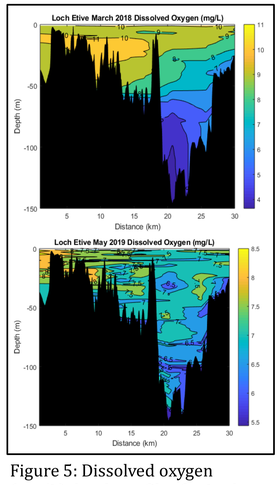


Figure 5: Dissolved oxygen (mg/L) depth profiles for Loch Etive for March 2018 (top graph) and May 2019 (bottom graph).

The dissolved oxygen levels for the water samples collected in March 2018 showed oxygenated surface waters and less oxic bottom water (Figure 5). Dissolved oxygen levels remained high 10-11 mg/L throughout at all depths in the lower basin, stations RE6-RE9. In the upper basin, the dissolved oxygen concentration decreased with depth, reaching concentrations as low as 4 mg/L the threshold for hypoxia. Unlike the March 2018 data, the May 2019 data did not show a stratified depth profile with respect to oxygen. Similarly to the March 2018 data, the water in the lower basin appeared to be more oxygenated than the water in the upper basin.

Discuss/Conclude

A flushing event occurred between March and May as stratification of temperature and salinity were vastly different and mostly uniform throughout the upper basin. We assume that the event occurred close to May 2019 as the dissolved oxygen levels were not greatly stratified and was 14 months after the previous flushing event. There was also lower rainfall (mm) beginning in March 2019, which is a necessary precursor to a flushing event as there is less freshwater input to create stratification.

These variabilities of environmental factors affect benthic organisms as well as fish farms within the top 10 meters of the loch. The benthic ecosystem recovers after a flushing event as oxygen and nutrients are resupplied at depth. Fisheries must manage the placement of species within Loch Etive to balance a wide variety of factors. Fisheries for blue mussels tend to be near the mouth of the loch as they prefer higher salinities. Rainbow trout fish farms placed further into Loch Etive as they can tolerate brackish water and salinity fluctuations. Although management works with scientists to predict flushing events, regulations are not in place to protect aquaculture throughout Loch Etive. Policies protecting aquaculture and farmers in Loch Etive should be considered as Loch Etive produces a large biomass of food for Scotland and other countries and aquaculture provides a socioeconomic base for the surrounding communities.

Literature Cited

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