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Application of passive-acoustic telemetry to explore the behaviour of ballan wrasse (*Labrus bergylta*) and lumpfish (*Cyclopterus lumpus*) in commercial Scottish salmon sea-pens

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ABSTRACT

A passive-acoustic telemetry system was used for the first time for the fine-scale, three-dimensional tracking of individual cleaner fish in commercial Scottish salmon sea-pens in full commercial operation. The aim was to test the system performance and provide baseline data on the comparative distribution and swimming activity of individual ballan wrasse and lumpfish under standard farm practices with the long-term aim of informing stocking and husbandry strategies. In March 2015, wild ballan wrasse (*Labrus bergylta*) (115 ± 20 g; $n = 13$) and farmed lumpfish (*Cyclopterus lumpus*) (281 ± 42 g; n = 13) previously deployed in June–October 2014 were recaptured, implanted with acoustic tags pinging every 6–12 s and released into their original sea cage holding Atlantic salmon (Q2 2014; 2059 ± 35 g mean-weight). Control tags were deployed in cleaner fish hides to validate the system performance. Positional data from nine specimens per species were analysed from March 24th to June 1st 2015, during which time water temperature rose from 7.2 to 9.1 °C and water salinity averaged 26.8 ± 1.5 ppt at 4 m depth. The accuracy of the acoustic positions averaged 0.6 m across the three dimensions of all control tags and was < 1 m in 93% of all cases. Significant differences in the distribution and activity of ballan wrasse and lumpfish were observed. Ballan wrasses spent 60 ± 2% of the day-time at or below 15 m, were positioned at significantly shallower depths at night and seldom used the hides provided despite an apparent resting behaviour at the pen bottom and corners. In comparison, lumpfish spent over 80% of the time above 10 m, used hides extensively and preferentially at night (50.1 ± 2.1% at night), but to a lesser extent when the water temperature increased. The acoustic tracking system proved to be an effective tool for visualising cleaner fish behaviour under challenging farm conditions, and the study highlights the critical role of hides in cleaner fish husbandry. Overall, the study quantified species-specific cleaner fish distribution in salmon net-pens supporting distinct interactions with the salmon stock and seasonal behaviour profiles. The results support the current commercial strategy of using two cleaner fish species against sea lice and the need for species-specific management strategies to optimise delousing activity.

1. Introduction

In recent years, cleaner fish have been implemented at a large scale in the North Atlantic salmon industry as a strategic component to the sustainable control of the potentially devastating salmon louse *Lepeophtheirus salmonis* (Boxaspen, 2006). This widespread and pivotal shift towards an integrated lice management relying heavily on biological control is unprecedented and unrivalled across intensively reared livestock. Although many challenges have been rapidly overcome to achieve the current level of biological delousing, the predictability and efficiency of this biological pest management strategy must be optimised across grow-out sites and through whole production cycles to ensure its long-term application and sector wide benefits. The implementation of effective biological delousing strategies must be informed by the requirements, behaviour and delousing activity of available cleaner fish species according to seasonal and local conditions and as a function of their origin and history.

The European industry is currently using wild-caught labrids, including ballan (*Labrus bergylta*), goldsinny (*Ctenolabrus rupestris*), corkwing (*Crenilabrus melops*), rockcook (*Centolabrus exoletus*) and cuckoo (*Labrus mixtus*) wrasse, in addition to farmed ballan wrasse and lumpfish (*Cyclopterus lumpus*) (Treasurer, 2013; Skiftesvik et al., 2014;

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Norwegian directorate of fisheries, 2013). However, the ambition is for total reliance on farmed specimens to secure sustainability and optimise biosecurity. Therefore, current efforts are increasingly focussed on the management of farmed ballan wrasse and lumpfish in cohabitation with salmon.

The ballan wrasse is a temperate species of the northeast Atlantic, with its range extending south to Morocco and north to Trondheim, Norway (Wheeler and Du Heaume, 1969; Quignard and Pras, 1986), and it is generally regarded as exhibiting diurnal behaviour, along with other European labrids (Costello, 1991; Turner and Warman, 1991; Darwall et al., 1992; Villegas-Ríos et al., 2013). They are nearshore-demersal fish being most abundant in shallow coastal rocky reefs and kelp beds at depths of 20–30 m (Dipper et al., 1977) and commonly shelter overnight in rock crevices (Costello, 1991). When deployed in salmon pens, therefore, shelters, or hides, should be provided for nocturnal resting and protection from predators, rough weather and during winter conditions. Recent delousing experiments and commercial results have suggested low swimming and foraging activity of ballan wrasse at temperatures below 9–10 °C (Treasurer, 2013; Lein et al., 2014) although high delousing was evident at 10.5 °C in flow-through tanks (Leclercq et al., 2014).

Lumpfish are widely distributed across the North Atlantic, including Greenland. Juvenile and adult lumpfish generally live offshore exhibiting a semi-pelagic behaviour and are often associated with floating seaweed (Davenport, 1985; Ingólfsson et al., 2002; Kennedy et al., 2016). Adults switch between demersal habitats in the winter prior to their spring spawning migration when they exhibit large diel vertical migrations as they move towards shallow inshore waters where they often attach to rocky substrates (Davenport and Kjørsvik, 1986; Kennedy et al., 2016). The lumpfish is considered a suitable cold-water cleaner-fish species in salmon net-pens as it rapidly adapts to an open net-pen environment and exhibits a clear sea lice predation behaviour (Budney and Hall, 2010; Imsland et al., 2014a, 2014b). It lacks a swim bladder but is almost neutrally buoyancy (Davenport and Kjørsvik, 1986). An abdominal suction disc formed by a modified pelvic fin (Budney and Hall, 2010) facilitates its natural propensity for surface adhesion (Imsland et al., 2015), and it has a low aerobic scope (Killen et al., 2007). Ballan wrasse and lumpfish exhibit distinct life histories, biological features and habitat preferences; therefore, their sustainable use as biological agents within a salmon farm environment requires the development of dedicated husbandry practices that preserve their health, welfare and survival throughout the salmon rearing cycle.

The key to the continual improvement of husbandry practices in any farming system is the observation of the livestock and the ability to rapidly identify deviations from normal behaviour and natural rhythms. However, the monitoring of cleaner fish deployed at low densities within commercial Atlantic salmon net-pens is difficult and remains largely anecdotal. Previous studies have either tried to extrapolate from tank studies (Leclercq et al., 2014; Imsland et al., 2016a) or using scuba diving observations and/or underwater video monitoring in experimental cage set-ups (Imsland et al., 2014b, 2016b) to provide valuable knowledge, but the scope of such work is constrained.

Passive-acoustic telemetry (as opposed to active acoustics where a transducer transmits sound pulses into the water and listens for echoes) uses underwater receivers (hydrophones) to listen for acoustic signals from aquatic animals fitted with acoustic transmitters, and is widely used in fisheries studies for survival studies and population monitoring (Heupel et al., 2006; Kessel et al., 2014; Pollom and Rose, 2016). Commonly, a fixed array of hydrophones is deployed across a known fish migration area (e.g. river or estuary) that records the movement of tagged fish through the array (e.g. Serrano et al., 2009; Roscoe et al., 2011) or a single mobile hydrophone setup is used to make transects of a study area and record the presence of tagged fish (e.g. Johnston et al., 2006). However, to the authors' knowledge, very few previous studies have used passive-acoustic telemetry in aquaculture net-pens (Juell and Westerberg, 1993; Rillahan et al., 2009, 2011; Føre et al., 2011), and these studies were in small experimental pens. More recently, Føre et al., 2017 compared acoustic transmitter tags containing biomonitors with data storage tags for tagging salmon in commercial net pens, although detection rates were < 50% in initial tests. Once fish are tagged and a hydrophone array is established, passive-acoustic telemetry can autonomously record fine-scale (sub-metre resolution), high temporal resolution (e.g. 1–60 s), three-dimensional positions of multiple individuals over a period of weeks to months, depending on the battery life of the tags (Kessel et al., 2014). For this reason, such systems have already been successfully used to describe behaviour of wild adult ballan wrasse (Villegas-Rios et al., 2013) and lumpfish (Mitamura et al., 2012), and the method is ideal for monitoring the fine-scale activity and behaviour of individual cleaner fish in salmon net pens in order to better understand the types of behaviours that relate to effective delousing. However, a commercial salmon farm is a challenging environment for acoustic telemetry due to regular underwater noise from farm operations, such as boat traffic, ADDs (Acoustic Deterrent Devices) and automated feeders, which may drown out acoustic tag signals, and underwater objects, such as the farm structure, nets and shoaling salmon, which may deflect or attenuate acoustic tag signals. Due to the significant influence of environmental and other factors on the performance and detection of acoustic receivers and the unique set of conditions found at every study site, it is important that these are carefully considered when designing a study system and that the system performance is tested thoroughly (Huveneers et al., 2016).

Therefore, the aims of this study were 1) to test the performance of a passive-acoustic telemetry system in an intensive net-pen aquaculture system under full commercial production, and 2) to generate preliminary baseline data on the comparative distribution and activity of the foremost cleaner fish species deployed within Atlantic salmon on-growing net-pens, ballan wrasse and lumpfish.

Unfortunately, it was not possible to acoustic tag salmon in this study as they were in commercial production, and tagging the salmon would introduce the risk of acoustic tags remaining in the final salmon product.

2. Materials and methods

2.1. Study site and animals

The study was performed in a commercial salmon sea site (56.69°N, 5.14°W, Loch Leven; Marine Harvest (Scotland) Ltd., UK) in two adjacent net-pens within a group of four floating square steel cages (HP 2000, Wavemaster, AKVA Group, Inverness, Scotland) each holding a double-sized net-pen (24 × 24 m square; 15 to 20 m depth inverted pyramid; 18 mm mesh) for in-situ biofouling control by switching the net bag and air-drying. At each pen corner, a ballast weight (1 t concrete block) was suspended from the steel cage structure using a chain to 20 m depth onto which a slider weight was fitted to maintain the net tension.

At the start of the trial, experimental pens contained Q2 2014 Atlantic salmon (n = 43,529 ± 1836, body weight = 2059 ± 35 g) and were stocked with either wild labrids (n = 3200; 7.2% of salmon stock, pen 8) or farmed lumpfish (n = 2396; 5.7% of salmon stock, pen 7) previously deployed into these pens in July and October 2014, respectively. The wild labrid population included ballan (57.9%, 78.2 ± 5.8 g, 167 ± 3 mm), goldsinny (*Ctenolabrus rupestris*; 29.9%), corkwing (*Crenilabrus melops*, 7.6%), rockcook (*Centolabrus exoletus*, 3.7%) and cuckoo (*Labrus mixtus*, 0.9%).

Atlantic salmon were fed a commercial extruded diet (BioMar (UK) Ltd) to visual satiation twice daily using surface rotor spreaders and underwater video monitoring (Akvasmart CCS feed system, SmartEye 360 twin camera; AKVA Group). Two sinking wrasse hides (1 m Ø weighted ring; 2 m high; plastic fake-kelp (Leclercq et al., 2015)) were suspended from a rope within each pen at opposite corners at 8–12 m depth (Fig. 1), adjacent to which water-stable cleaner-fish feed blocks