Report on the welfare of cleaner fish used in the Scottish salmon industry

Scottish Animal Welfare Commission

November 2025

Scottish Government
Riaghaltas na h-Alba

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Introduction

1. The Scottish Animal Welfare Commission (SAWC) was established by the Scottish Animal Welfare Commission Regulations 2020, made under section 36 of the Animal Health and Welfare (Scotland) Act 2006. The function of providing advice on the protection of wildlife under section 23 of the Wildlife and Countryside Act 1981 has been assigned by Ministerial declaration.

Further information on the Commission, including reports and minutes of previous meetings, is published when available on its web page.

2. SAWC's terms of reference are to focus on the welfare of wild and companion animals in Scotland while also providing scientific and ethical advice to the Scottish Government. The Commission will only consider areas that are within the normal current remit of the UK Animal Welfare Committee and the UK Zoo Expert Committee where these relate to the overall responsibility to consider the welfare needs of sentient animals in all areas of Scottish Government policy or at the specific request of the Scottish Ministers. The Commission will not consider matters that are reserved to the UK Government, including the welfare of animals used in scientific procedures.

The Commission, which is independent of the Scottish Government, provides written reports and opinions to Scottish Ministers giving practical recommendations based on scientific evidence and ethical considerations on the welfare of sentient animals in Scotland, and the impact of policy on welfare.

1. Scope

Sea louse infestation is a major health, welfare and production issue for the Atlantic salmon (*Salmo salar*) industry. This is a major problem affecting many countries farming Atlantic salmon, however, our focus will be on the effect on the farming of Atlantic salmon in Scotland in particular. In recent years, the use of ‘cleaner fish’ (fish species which have naturally occurring specialised feeding behaviours where they remove parasites from the gills and skin of other fish) has become an established part of the ‘toolbox’ of methods used by the industry to control numbers of sea lice. However, the welfare of the cleaner fish, as a sentient animal managed within the salmon farming industry, needs to be considered in its own right in addition to the welfare of the salmon. Therefore, the aim of this report is to consider the welfare of the two main species of cleaner fish (ballan wrasse (*Labrus bergylta*) and lumpfish (*Cyclopterus lumpus)* used in the Scottish Atlantic salmon industry.

2. Background and definition of area of analysis

Prevention and control methods for sea lice

Cleaner fish are used as biological control agents for sea lice. There are two main species of sea louse found in Scottish waters: *Lepeoptheirus salmonis* and *Caligus elongatus.* Sea lice feed on the mucus, skin and blood of the fish. Moderate to high infestations cause damage to exposed surfaces of the fish, and subsequently osmoregulatory failure, immunosuppression and chronic stress (Grimnes and Jakobsen, 1996, Bowers et al., 2000). Infestation also facilitates infection by other pathogens leading to disease (Cai et al., 2024). See Appendix VI for a diagram of the life cycle of *Lepeoptheirus salmonis*.

To combat sea lice, the salmon industry uses a suite of preventative measures including the use of physical barriers to prevent ingress of the lice, feeding the salmon at or below the depth that lice typically inhabit and choosing locations of the farms where sea lice are less prevalent (Barrett et al., 2020). Once salmon are infested, a number of treatments can be used to reduce the numbers of lice, including chemotherapeutics, hydrogen peroxide, thermal and physical treatments, and cleaner fish (Overton et al., 2019). Chemical or fresh/brackish-water treatments can be used for the larval, sessile and mobile (pre-adult and adult) stages, while physical methods (such as the Hydrolicer) and thermal delousing methods (e.g., the Thermolicer) can be used for the sessile and mobile stages (Overton et al., 2019). Cleaner fish are used only to control the mobile stages (Barrett et al., 2020). See the glossary for definitions and Appendix VI for a description.

History of the use of cleaner fish in the salmon industry

In the 1990s, a number of species of cleaner fish were trialled for use in reducing sea louse infestations, but due to an increase in availability of chemical control methods and biosecurity issues with the species of cleaner fish used in that period, the use of cleaner fish declined (Treasurer et al., 2024). However, since about 2008 (Treasurer, 2018), there has been a resurgence of interest in the use of cleaner fish, because of stricter controls on the use of chemotherapeutics and reduction in efficacy of these treatments due to adaptations by the sea lice, plus the growing concern over the increase in mortality in the salmon after the use of the thermal and physical treatments (Overton et al., 2019). The use of a biological control agent is also likely to be more compatible with consumer expectations.

Because the use of cleaner fish is relatively new, knowledge on the best way to rear and manage them is constantly being generated through continuing research and practical experience within the industry, research institutes and universities. As such, the picture is constantly evolving. This project presents the situation as it was when the data were gathered from late 2023 to mid-2025.

Species of cleaner fish used

There are two main species used as cleaner fish in Scottish aquaculture: ballan wrasse (*Labrus bergylta*) and lumpfish (*Cyclopterus lumpus*) (See Appendices IV and V for further details). Both species are 'facultative' cleaners, which show flexibility in their foraging choices between cleaning and use of other food resources, rather than being 'dedicated' cleaner fish that only eat the external parasites of specific hosts. Although various other species of cleaner fish were trialled early in the establishment of salmon farming in Scotland and have been used (mostly other species of wrasse), our evidence gathering revealed that the two species named above are now the most common. Salmon companies may use both or just one species. The two species may be used on one farm, because they are adapted to different thermal conditions of the water. Lumpfish are more effective in cold water and so may be used at higher latitudes or during the winter months, while wrasses are more effective in warmer conditions.

Wild caught vs. captive-reared cleaner fish

Currently, the ballan wrasse that are used as cleaner fish may be captured directly from the wild or may be reared onshore in tanks in specialist rearing facilities. The broodstock held in the rearing facilities may also be wild-caught or captive-bred (see Section 4.1 for more details). The different rearing environments mean that the two populations of fish are vulnerable at different points in their life cycles. For instance, the strong water currents, low water temperature and variable light conditions of the salmon sea pens may affect the captive-reared cleaner fish more than the wild-caught individuals. Accordingly, we consider welfare effects on the fish from each background separately, where necessary, in the following analysis. Additionally, because the wild-caught fish are essentially translocated from their origin sites, the principles outlined in SAWC's 'Wild Animal Translocations: Animal Welfare Risk Assessment Guidance' document (2025) are considered where appropriate.

Industry dynamics

During the course of the evidence gathering in this report it became apparent that use of lumpfish was declining, or had stopped altogether, and that the majority of Scottish salmon producers were focused on the use of ballan wrasse. Therefore, we will focus predominantly on ballan wrasse and their welfare in this report, as this reflects the current Scottish situation. For completeness, some mention of the situation with regards to lumpfish is included. Where the welfare of lumpfish is likely to be considerably different from ballan wrasse, we will also mention those specific issues.

3. SAWC evidence gathering and analysis

- The SAWC Aquaculture working group held an initial interview with a representative of Salmon Scotland (Oct 2023) to scope out the idea of the project and to understand what is known about the use of cleaner fish in Scottish aquaculture.
- A literature review was carried out to gather information on the role and efficacy of cleaner fish within the salmon industry globally.
- A visit was made to the Otter Ferry Seafish facility on Loch Fyne in February 2024, where ballan wrasse are bred and reared in captivity.
- Interviews were held in March and April with 2024 with cleaner fish managers of four of the major salmon producers in Scotland, and company staff involved in fish health and welfare.
- A list of outstanding questions was sent to Salmon Scotland for further clarification.
- Discussions were held with a number of non-governmental organisations with an interest in animal welfare about their views on the welfare of cleaner fish in 2025.
- An ethical analysis was undertaken.

4. Outcomes of evidence gathering

Structure of the review of evidence

The lifecycles of the fish species used as cleaner fish are complex and, in some cases, lengthy. In addition, the lifecycle of sea lice is relevant to this discussion. An overview of these cycles is given for information in Appendices IV, V and VI.

It became clear that there are a number of points across the lifetime of the cleaner fish where welfare issues are more likely to arise. It was also clear that at some of these points there are different issues for the two different cleaner fish species, and for the wild-caught and captive-reared wrasse. Therefore, the analysis considered the two species separately where appropriate, as well as considering the welfare impacts of captive rearing and wild capture.

Additionally, there were some important overarching questions that were addressed, particularly with regard to the numbers of cleaner fish deployed and their subsequent losses, as well as the effectiveness of cleaner fish in reducing sea louse infestation in comparison to other methods of reducing or removing sea lice.

Finally, the ethics of the use of cleaner fish within the salmon farming industry was considered. An ethical review was conducted to consider the farming of one type of animal (the cleaner fishes) to aid the health, welfare and production of another species (the salmon). To our knowledge, this situation is unique in aquaculture and terrestrial livestock production.

The text of this report is based on the outcomes of the interviews with stakeholders as well as information from a review of the relevant literature. Published reports and literature are cited and are shown in the reference list.

4.1 Cleaner fish lifecycles – a pen picture

Ballan wrasse

The ballan wrasse (*Labrus bergylta*) that are used as cleaner fish in the Scottish salmon industry are either wild-caught or bred and reared in specialist facilities. Wild-caught fish are mainly fished from waters on the west coast of Scotland, the Inner and Outer Hebrides and Orkney (Scottish Government, 2022), with some fish coming from Northern Ireland and other northern areas of the UK, and deployed into the salmon sea pens. Farmed ballan wrasse are reared in specialist onshore facilities that produce large numbers of these fish for Scottish and overseas markets. Movements of fish are subject to health certification where relevant.

In the case of captive rearing, broodstock are kept in tanks at the rearing facility. The species is a protogynous hermaphrodite, with some females transforming into males from about 6 years of age (Leclerq et al., 2014). After fertilisation, eggs from the broodstock are transferred to a hatching tank, and once hatched, they are reared in a series of tanks according to wrasse size until they reach the appropriate size for deployment onto the salmon farms. Live food is provided for the larval stages, as this is important in promoting their survival (Brooker et al., 2018). The fish are between 18 months and two years old when they are ready to be used on the salmon farms.

Towards the end of the period in the rearing facilities and possibly also once at the salmon farm in a period before deployment into the salmon sea pens, the ballan wrasse undergo a period of 'conditioning'. This involves exposing the fish to the conditions of water temperature, lighting, and food type and presentation that will be found in the sea pens. This is done to accustom the fish to the conditions found in the sea pens. The fish remain in the sea cage until the end of the salmon growth cycle. In most cases, they are not redeployed into another salmon cage, as there is a risk that they might carry disease from the previous pen to a pen of naive salmon (see Appendix V).

Lumpfish
Lumpfish are typically reared in specialist facilities. Lumpfish eggs may be collected from the wild (e.g., from Icelandic or Norwegian waters), or broodstock are captured from the wild or kept at hatcheries (Powell et al., 2017; Treasurer et al 2024). Fertilised eggs are collected and the fish are reared through their developmental stages in tanks within the hatcher. They are ready for deployment on salmon farms when they are about 10g in weight and between 6.5-7 months of age (Powell et al., 2017).

4.2 Key stages across the lifecycle

4.2.1 Capture and transport of cleaner fish from the wild for deployment in sea pens

Ballan wrasse
Some companies prefer to catch all or a proportion of their ballan wrasse from the wild rather than breed and rear them in onshore facilities (see note below on relative effectiveness of wild vs farmed wrasse in sea lice control).

Licensed fishers are used to catch the ballan wrasse ideally from sites close to the salmon farms, so that the fish are adapted to the local environmental and water conditions. In 2022, 63 derogations (an addition to their domestic fishing licence) were issued for wrasse to fishers, and 78.6 tonnes of wrasse were landed, with 80.6% of the catch being ballan wrasse. Fish were landed on the west coast of Scotland and in Orkney. Of these, 25.8% were returned as they were under- or oversized (Scottish Government, 2024b). Suitably-sized fish are deployed directly into salmon pens but some are also used as broodstock.

Fishers are covered by regulations from the Marine Directorate (Scottish Government, 2022) that specify the maximum and minimum size of fish that can be landed, the requirement to use live traps and to ensure welfare when lifting traps from the water (traps must be raised slowly to prevent the swimbladder from bursting). The size range for wild-caught ballan wrasse has been changed from 12-24 to 14-24 cm whilst additional modelling work is being carried out (Scottish Government, 2025). RSPCA welfare standards also cover the capture of wild wrasse and include stipulations on methods of capture, raising the creels or pots slowly, and maximum water temperatures at capture (high water temperatures cause greater stress). Most of the salmon companies operating in Scotland are members of the

RSPCA Assured farm assurance scheme. Fishers are also audited by the purchasing company. Because cleaner fish command a good price (between £10-15/fish (Scottish Government, 2024b)), it is in the interest of the fishers to keep mortality to a minimum and deliver the fish in good condition.

Welfare concerns
The care and skill of the fishers are critical to the experience of the fish being caught. Capture, and removal from the wild, likely has a negative impact on the welfare of the captured fish. The fish that are captured, but returned due to being too large or small, will also have a negative experience or potentially incur injuries. Welfare does not appear to be formally monitored in the post-capture period using recognised indicators.

Additionally, there are concerns from conservation groups and the industry about the sustainability of the native wrasse fishery, in particular whether local populations of fish are being depleted due to removal of fish for use on salmon farms. The Marine Directorate set controls on the wrasse fishery in 2021, which aimed to restrict fishing to sustainable levels. These regulations require licensed fishers to apply for an annual letter of derogation to catch wrasse within the permitted season to allow for breeding and impose restrictions on the size of wrasse caught, number of pots (traps) set and data that must be returned (Marine Directorate, 2022). Large numbers of wrasse are also bought in from other parts of the UK, particularly Northern Ireland. The effects of removal of cohorts of animals of the size required for use as cleaner fish on the overall natural populations is currently unknown, but there is the potential for a negative impact.

4.2.2 Capture and management of brood stock

Ballan wrasse
Female wrasse used as broodstock may be caught from the wild or reared in specialist units. As noted in paragraph 4.1, the ballan wrasse is a protogynous hermaphrodite species, where some females change into males from 6 years of age (Leclerq et al., 2014). It is thought that the most dominant females change sex (Muncaster et al., 2013). Due to regulations on landing sizes (which define the upper and lower limit at which fish can be caught from the wild), hatcheries must currently keep groups of females until some have transitioned into males, as male fish will typically be larger than those that can be caught from the wild. Brood stock is kept in tanks containing hides in onshore facilities (such as at Otter Ferry Seafish). It is standard practice to establish a 1:4 male to female sex ratio (Grant et al., 2016) in these tanks.

Lumpfish
Currently, some facilities in England and Wales have captive broodstock that produce eggs that are reared to a suitable size in these sites before transfer to Scotland (Treasurer et al., 2024). However, it is likely that production at these facilities will cease due to the recent move away from the use of lumpfish. In other case, eggs are sourced from the wild in Norway or Iceland, subject to health certification, and reared in hatcheries.

Welfare concerns
It is likely that there are considerable physical and social differences between the wild and the captive environment experienced by the broodstock animals, including water quality and temperature, food types, social structure and environmental complexity. Broodstock animals kept in captivity do not have the freedom that their wild counterparts do, and tanks are less enriched than the wild environment, but predation and probably disease risk will be lower, and food provision may be better. The practice of breeding and rearing cleaner fish in these facilities is relatively new, so changes are constantly being made to their management procedures to improve fish survival and husbandry. Fish caught from the wild for use as broodstock may also experience stress during the process of capture and transport.

4.2.3 Care and management of cleaner fish during the rearing period in onshore facilities

Ballan wrasse
Fish are reared from eggs in dedicated facilities. In 2023, 8 tonnes of cleaner fish were produced, while in 2024, the total production was 6 tonnes (with no differentiation between the species – Scottish Government, 2024a)).

The different developmental stages of the fish are kept in different seawater tanks with environmental conditions appropriate to their lifestage. Lighting and temperature are controlled. Live feeding is provided for the larval stages, as this has been shown to be very important for development (Helland et al., 2014). For the older stages, food is provided, and enrichment (artificial kelp/plants for shelter) is typically used. Rearing conditions are covered by RSPCA guidelines that specify hygiene, feeding and other husbandry practices (RSPCA, 2024)

A ‘conditioning’ period is used in the month before the fish are sent to the salmon farms. The aim of this conditioning period is to acclimate the fish to the conditions that are found in the sea pens, in particular the low water temperatures, diurnal light/dark patterns and method of presentation of food. Thus, in this period the fish are moved from a constant feeding regime to being given food blocks, which is how feed is delivered in the sea pens. Hides are provided that are similar to those found in the sea pens, and the lighting and water temperature are changed to those which they will experience in the sea pens.

Fish are vaccinated for atypical furunculosis, *Aeromonas salmonicida* and *Vibrio anguillarum*.

Lumpfish
A rearing facility for lumpfish is located in Anglesey, Wales. Tanks containing seawater are used to rear the fish in an indoor facility. Acclimation pens are also reported to be used in the rearing of lumpfish. However, as noted above, the demand for lumpfish in salmon farming is declining.

Welfare concerns
As for the broodstock, there is the potential for welfare harms if all aspects of care and management, such as water quality, stocking density, food quality and provision

and enrichment, are not provided or maintained at a high standard. As the keeping of cleaner fish is relatively new, there is much to learn about their husbandry, and there may be welfare compromises for fish whilst their needs are being fully researched and 'best practice guidelines' are being established.

4.2.4 Transport of cleaner fish from rearing facility or point of wild capture to the salmon farm

Both species of fish are transported from the onshore rearing facility on a lorry carrying large seawater tanks. Wild-caught fish are also transported in tanks. Transportation is also covered by the RSPCA Assured standards (2024), which prescribe limits for stocking density, water temperature differentials between the sea and the tank in the case of wild-caught fish, and oxygen saturation in the transportation tanks.

Welfare concerns
As for any transportation event, the health and welfare of the animals depends on the use of appropriate methods and the quality of care taken during on-loading and off-loading, and conditions during travel. The water quality, oxygenation levels and temperature of the water in the transportation tanks must be the same as the seawater for wild-caught fish or the same as the rearing tanks in the case of the captive-reared animals. Stocking density must also be correct. Noise and vibration are additional causes of stress during transportation (Leggatt et al., 2006).

4.2.5 Deployment of cleaner fish on salmon farms

Acclimation period and introduction to the salmon sea pens
In some farms, the cleaner fish are introduced directly into the sea pens with the salmon. In other farms, there is a further period of acclimation on the site of the salmon farm, in a process akin to a ‘soft release’ procedure for translocation of wild animals. In this process, the fish are put into a small sea (or ‘keep’) pen that may be separate from, but contained within, the salmon pen. This allows the cleaner fish to recover from transport and become acclimatised to the ambient sea and climatic conditions, as well as the feeding and other management systems, before release into the main salmon pen.

The RSPCA has guidelines for the introduction of cleaner fish into the sea pens, which state that health and welfare checks should be made as the fish are put into the sea pens and daily thereafter, that hides are available and mortality is monitored.

Specialised staff
All of the interviewed companies have specialist staff specifically trained to manage their cleaner fish. In most cases, this was a specified individual whose sole job was to provide husbandry for cleaner fish. SalmonScotland stated that this is the case for most major salmon production companies.

Welfare checks
In many companies, welfare checks are carried out on the cleaner fish, using a set of operation welfare indicators (OWI) specifically designed for cleaner fish. OWI lists

have been created specifically for the cleaner fish species used (e.g., Noble et al., 2019), but the extent of their use is not clear. One company stated that ten fish are caught for checks made on body condition, health and the presence of injuries (eyes, fins).

Mortality is monitored. One company reported that if mortality exceeds 2%/week, a vet visit is triggered.

Health management
Cleaner fish are vulnerable to disease. Wrasses are currently vaccinated against atypical furunculosis (AF) and *Vibrio anguillarum* in the rearing facilities. There are reports of outbreaks of other diseases (e.g., viral haemorrhagic septicaemia (Hall et al., 2013) but these are uncommon. Lumpfish are vaccinated against *Pseudomonas* spp. Wild-caught wrasse are not vaccinated, because the procedure requires handling, which is stressful to the fish, and there is a trade-off between the benefits of vaccination vs. the stress of handing. Ballan wrasses with AF are culled.

Treatments for other conditions may involve the cleaner fish receiving the same treatments as the salmon. Cleaner fish are tested for amoebic gill disease (AGD), which is caused by the amoeba *Paramoeba perurans*, and may be treated using peroxide or freshwater treatments, although it has been shown that ballan wrasse are less susceptible to AGD than salmon (Dahle et al., 2020), so fish may not require treatment in all cases. Cleaner fish can also be infected with sea lice, and they will receive the same treatment as the salmon. New regulations from the RSPCA require that cleaner fish are removed from the salmon pens before treatment (RSPCA, 2024). Most Scottish salmon companies are members of the RSPCA Assured scheme. Some companies use a thermolicer and others use freshwater treatments. The freshwater treatment can also be effective for AGD. Freshwater treatment involves creating a 'bath' of freshwater and keeping the fish in this bath for 3-4 h with additional oxygen (Powell et al., 2015). Freshwater loosens the attachment of the sea lice, so that the application of low-pressure water jets can remove the lice. Both the thermolicer and the freshwater treatment require gathering the fish from the sea pen, which involves crowding them and the use of pumps to move them from the sea water to the baths and back again. Cleaner fish may experience stress and there is a possibility of injury during this process.

Resources provided for the cleaner fish
The industry Code of Good Practice contain a number of recommendations regarding the care and management of cleaner fish including resources and staff training (Scottish Finfish Aquaculture, 2016). Cleaner fish are provided with feed blocks within the salmon sea pens. The core of the blocks floats up to the surface when the edible section has been consumed, and they need replacing. Originally it was thought that the fish would survive entirely by consuming the sea lice from the salmon, or that keeping them slightly hungry would encourage them to consume more sea lice, but more recent evidence demonstrates that providing a consistent source of food is essential. Wrasses have a 'grazing' food strategy, as they have no stomach or pyloric caeca and need to feed constantly (Lie et al. 2018; Norland et al., 2022). The number of blocks used depends on the numbers of fish and the season.

Hides or shelters are provided for the cleaner fish. Hides are typically plastic strips or artificial kelp (Helland et al., 2014) or may be natural kelp. Artificial kelp is typically provided in rings or in ‘corridors’, which are up to 5m in length. Corridors are used in larger sea pens and allow for better interaction between the cleaner fish and the salmon, if sited and orientated appropriately. However, studies have observed that wild-caught wrasse do not typically use the hides provided (although they stayed close to them), although hatchery-reared wrasse and lumpfish were observed to use them (Leclercg et al., 2018; Brooker et al 2020).

Handling during salmon treatment events

When the need arises, the salmon may be removed from the sea pens for treatment, grading or slaughter. This can be achieved by providing hides or creels for the cleaner fish to enter, so that they can be removed before the salmon are crowded for treatment. Ballan wrasses may also be separated out using the de-watering devices used for removing water from waste products, or the grading equipment. While the salmon company interviewees stated that they avoid gathering the cleaner fish in as well, if at all possible, from May 2025 the RSPCA standards stipulate that cleaner fish must be removed from the ‘crowding’ net or prevented from entering it, prior to any salmon treatment event. The salmon company representatives reported being concerned that separating out the cleaner fish would be difficult to fully achieve operationally.

This issue is more pertinent to lumpfish, as the interviewees stated that it is more difficult to separate the lumpfish from the salmon before any treatment. They are not attracted to the baited creels used for ballan wrasses and can stick themselves to the metal surfaces of the dewatering device. A lubricant has been developed to try to prevent this. A method of providing hides to attract them, which can then be removed from the pen before the salmon are crowded, is also an option, but the efficacy of these methods is unknown. These issues with handling lumpfish have been reported as a challenge and have contributed to a reduction in the use of lumpfish.

Slaughter vs. re-use at the end of the salmon production cycle

Currently, most of the cleaner fish are euthanised when the salmon are slaughtered at the end of their production cycle. The Scottish salmon industry’s Code of Good practice recommends that a risk assessment is done at the end of each salmon cycle, and that it considers the health status of both the cleaner fish and the salmon (Scottish Finfish Aquaculture, 2016). In many cases, the possibility of transmitting disease or sea lice from one generation of salmon to the next precludes cleaner fish being re-used in a new generation. Additionally, the need to maintain an appropriate size disparity between the salmon and the cleaner fish must be considered. In particular, the lumpfish are usually considered to have grown too large for re-use by the end of a salmon cycle. It is possible for ballan wrasses to be re-deployed, and some companies prefer to do this to allow ‘experienced’ cleaner wrasse to aid habituation and ‘training’ of naïve wrasse. However, interviewees stated that in practice re-use typically does not occur due to biosecurity concerns.

Currently, the cleaner fish are separated from the salmon and euthanised. An overdose of anaesthetic or electric stunning is typically used. The use of culled cleaner fish as a protein source in other applications, such as pet foods, is unclear.

Welfare concerns
As for most animal welfare issues, whether the cleaner fish experience good or poor welfare depends largely on the opportunity, ability and motivation of the people looking after the fish to do a good job. There are written welfare standards available, and staff with responsibility for the cleaner fish are employed, so the necessary elements are in place. The provision of hides and food blocks has been studied, but more research is likely needed to understand the best method of presentation to encourage use. The maintenance and provision of the resources also depends on the diligence of the cleaner fish managers and farm staff, and additionally on the willingness of the salmon companies to invest in the physical resources and the time and training of the staff. Disease control in cleaner fish is also an area where research is needed. There are difference levels of tolerance for disease treatments such as freshwater treatment, between the salmon and the cleaner fish, so the most appropriate treatment should only be applied to the species that requires treatment.

4.3 Other deployment issues identified

4.3.1 Encouraging interactions between cleaner fish and salmon

The cleaner fish and their resources have to be managed to promote the removal of sea lice from the salmon by the cleaner fish. This includes the placement of the hides and the regulation of food availability for the cleaner fish. The hides, where the cleaner fish locate themselves, have to be placed in the sea pens in such a way that the salmon encounter them. Some studies have shown that the diurnal movement patterns of wrasses and their preferred swimming depths is different to those of the salmon, which may limit the opportunity for them to interact (Overton et al., 2020). Ballan wrasses are agastric 'grazers' and need to have a constant food supply. They will turn to other food sources if sea lice are not readily available. Thus, the nets of the pens need to be kept clean of algae, as they will use this as a food source, rather than foraging on sea lice (Treasurer, 2002). More needs to be known about how to best facilitate cleaner fish-salmon interactions to facilitate sea lice removal. This is an area on which the salmon companies are actively working.

It is thought that cleaning is an innate behaviour of the cleaner fish. In support of this, neuropeptide pathways have been identified that appear to control cleaning behaviour (Soares et al., 2012). However, it is likely that learning processes refine the behaviour and make it more efficient, including learning what sea louse species are present in a locality. The discussions with the salmon company representatives suggested that the naive cleaner fish and the salmon need to learn their roles. Studies in other species of cleaner wrasse have shown that juvenile fish use social learning strategies to refine their interactions with 'clients' (Truskanov et al., 2020), indicating that learning from experienced fish is important.

However, there is a danger that the salmon may predate the cleaner fish, or that the cleaner fish may attack the salmon (Treasurer et al., 2024). To avoid this, the size disparity must be right (salmon larger than the cleaner fish), and the salmon must be well fed.

4.3.2 Effectiveness of wild vs farmed ballan wrasse

There is some debate about the ability and motivation of captive-reared wrasses to forage on sea lice. A Norwegian study investigating lice removal rates of wild-caught and captive-reared wrasse in small experimental pens found no difference in the number of lice removed (Skiftesvik et al., 2013), However, a number of the Scottish salmon farming companies stated that farm-reared ballan wrasses are of poorer physical quality, exhibit higher levels of liver disease and have higher mortality compared to wild-caught fish. A larger study in sea pens showed that wild-caught wrasses were more active, had larger home ranges and showed more diurnal variation in behaviour than captive-reared wrasses, all of which are likely to lead to greater numbers of encounters between salmon and cleaner fish. The study also investigated the effect of a period of acclimation at the hatchery vs. two periods of acclimation, both at the hatchery and then in a 'keep net' within the sea pen, and concluded that only the dual acclimation strategy had any positive effect on behaviour (Brooker et al., 2020). This concurs with industry experience, as those interviewed stated that the use of an acclimation period improves the performance of the captive-reared wrasses.

Additionally, the farmed ballan wrasses are considered by the industry to be less effective at 'working' or removing sea lice. The interviewed salmon companies suggested that captive-reared ballan wrasses have to be stocked at higher ratios (cleaner fish to salmon) than wild-caught fish (e.g., farmed wrasses stocked at 6-8% of the salmon population compared to 2.5-4% when using wild-caught wrasses). It was stated that wild-caught ballan wrasses appear to be more effective and motivated to eat sea lice than captive-reared wrasses, at least in the initial period after introduction to the salmon pen. Producers stated that wild-caught wrasses start eating sea lice immediately upon transfer to the salmon sea pens, whereas captive-reared wrasses take some time to start to forage on the sea lice, in some cases up to 2-3 weeks after introduction. A recent study confirmed the idea that wild-caught wrasses are more active and interactive, with results showing that wild-caught wrasses show more 'confidence' in approaching a novel object compared to farm-reared wrasses, and that they swam in all areas of the sea pen, whilst the farm-reared fish tended to swim at the edges of the net (Brooker et al., 2021). The producers suggested that keeping wild-caught and captive-reared wrasses together allows the captive-reared wrasses to learn the cleaning behaviour, which may allow captive-reared wrasses to benefit from social learning as discussed above.

4.3.3 Changing patterns of use of the two major cleaner fish species

Through the course of the data gathering for this project (starting late 2023-mid-2025), some companies reported that they had stopped using lumpfish. This is because of problems with their robustness, separating them from the salmon and managing them during interventions. Lumpfish will stick to hard surfaces, do not voluntarily enter creels as ballan wrasses do, and their spherical conformation means that they are difficult to separate out from salmon using a standard dewatering/grading device.

Additionally, the effects of climate change mean that seawater temperatures around Scotland have become warmer, favouring the use of ballan wrasses, as least at lower latitudes. Some producers stated that lumpfish were considered to be less effective at removing sea lice, as they are considered more likely to use alternative feed sources, such as algal growth on nets. Some salmon companies still use some lumpfish, but their use is declining.

4.4 Additional issues and considerations

4.4.1 Numbers of cleaner fish deployed and losses on Scottish salmon farms

Salmon Scotland stated that 2 million lumpfish and one million wrasses are used in salmon farming. The Scottish Fish Farm Production Survey figures showed that 143,000 cleaner fish (both species) were produced on farms in Scotland in 2023, with 600,000 bought in from other parts of the UK (Scottish Government, 2024a). It was reported that these fish do not come from Southern England due to the potential for overfishing there. In addition, 19,800,000 cleaner fish were sold out of Scotland, mostly in the larval stages for on-growing outside of Scotland. At the company level, one of the major companies stated that 450,000 captive-reared ballan wrasses, 650,000 wild-caught wrasses and 1.6 million lumpfish from wild-sourced eggs from Norway were used. Otter Ferry Seafish produced 85,000 ballan wrasses for the Scottish salmon industry in 2024, and hoped to rear more if demand increased.

One farm interviewed stated that based on the number of dead cleaner fish recovered vs. the number put into the sea pen, mortality was estimated at 0.076% within the first 48h after introduction. Overall survival is 78.6% across the cycle (compared to 82% for salmon). Other companies state that losses can be high, but many do not have the figures available. High levels of loss have also been reported in research projects, (e.g., 57% for ballan wrasse and 27% for lumpfish (Geitung et al., 2020)). This high mortality rate was thought to be the result of poor food intakes, despite the use of food blocks, suggesting that the issues are not confined to cleaner fish within the salmon farming industry.

The loss of cleaner fish is one of the biggest concerns of the salmon companies and of welfare NGOs. High mortalities and incidence of disease in cleaner fish have also been reported by the industry in Norway (Nilsen et al., 2014), and high rates of mortality have been shown in experimental studies (e.g., Geitung et al. 2020). It is not clear what causes the losses or disappearance. Predation by the salmon, mortality due to handling, escapes or disease are possible causes (Overton et al., 2020). Ballan wrasses settle at the bottom of the sea pens in a resting torpor at night and may be taken by seals. Lumpfish carcasses breakdown quickly, so dead fish are not identified and counted. Cleaner fish mortalities may not be easily identifiable from the dead salmon (salmon mortality is checked weekly). One of the salmon companies described an experiment in which transponders were fitted to fish ended with the transponders being recovered from the seabed, suggesting that the fish died and the tags dropped through the net.

Welfare concerns
The mortality and the explained and unexplained losses of cleaner fish are a major concern. While some of the fish may escape through the netting of the sea pens, it is likely that the majority die and decompose, are eaten by the salmon, predated by other species, such as seals, or succumb to disease.

4.4.2 Effectiveness of cleaner fish: comparison with other methods of sea louse control

Cleaner fish are seen by many in the salmon farming industry as the first line of defence against sea lice. They are also seen as a ‘preventative’ measure, because the aim of their use is to keep the numbers of sea lice down to manageable levels, thereby avoiding the use of physical, chemotherapeutic or thermal delousing treatments. However, it was reported that there may be instances when the level of sea louse infestations can ‘overwhelm’ the ability of cleaner fish to remove the lice. At this point, some other treatment would be necessary. One company stated that about one-quarter of their sea louse control budget was spent on cleaner fish. A number of companies stated that they only used cleaner fish at certain times of year when sea lice are prevalent. Others stated that some farms only require cleaner fish to control sea lice. Patterns of mortality in cleaner fish across the saltwater phase of production may also influence the perception of cleaner fish efficacy. If mortality has been high, then there may be fewer cleaner fish to control the emerging population of the older stages of sea lice.

A review literature made by Overton et al., (2020) reported a wide range of efficacies of sea louse removal by cleaner fish from a 28% increase to a 100% reduction in sea louse numbers. Papers and reports from Scotland were included in the analysis. However, many of the reported studies were done in small experimental tanks, and none of the studies were carried out in exposed ocean sites. Higher efficacies were reported for ballan wrasses, with lumpfish being more variable in their success. A study using data from national louse counts, delousing treatments and cleaner fish stocking events from Norwegian salmon farms (which largely used lumpfish) showed that the use of cleaner fish reduced the lice populations only by a small amount, but their use delayed the use of other treatments (Barrett et al., 2020).

In comparison, a Scottish study showed that the efficacy of cleaner fish in reducing sea lice numbers was rated by experts as better than some other methods, such as in-feed medicine or hydrogen peroxide treatments (range of efficacies: cleaner fish 0.60-0.90; in-feed medicine: 0.50-0.80; hydrogen peroxide: 0.10-0.60), but lower than for Hydrolicer (0.70-0.95) or Thermolicer treatments (0.70-0.95). A combination of methods, including the use of cleaner fish, was considered to be the most effective with efficacies reported to reach 100% (Boerlage et al., 2024). These figures derived from expert opinion accord with the little published data available (e.g., up to 95% effectiveness of chemotherapeutic, but highly variable (Jimenez et al., 2013)). The use of cleaner fish as a sea louse control method has a lower impact on the welfare of the salmon. Negative impacts of cleaner fish on salmon are not reported, but significant salmon mortality can be observed when thermal, physical or chemical treatments are used. Salmon mortality during these treatments is affected by factors such as water temperature, fish size and pre-existing conditions in the fish population (Overton et al., 2019).

4.43 Factors affecting effectiveness of cleaner fish

It appears that the specific conditions of the site and the climatic conditions influence the effectiveness of cleaner fish in sea louse control. Factors, such as stocking density, presence of other food sources (such as fouled netting), and water temperature, affect the ability and motivation of cleaner fish to remove sea lice from the salmon (Brooker et al., 2018).

Management factors also affect cleaner fish activity. The size of the cleaner fish relative to the salmon has to be correct. The cleaner fish must be smaller than the salmon. Stress reduces the efficacy of cleaner fish. Having an appropriate acclimatisation period before the cleaner fish are put into the salmon pen is important in promoting optimal cleaner fish activity.

Genetic factors also appear to play a role. A study showed that there is variation between families of lumpfish in their sea louse foraging, indicating that there is a genetic basis to sea louse removal by these cleaner fish (Imsland et al., 2016). A study carried out by a salmon company that involved sacrificing cleaner fish showed that some individuals had more lice in their stomachs than others, indicating variation between individuals in their willingness to perform sea louse removal.

5. Ethical review

The aim of the ethical review was to consider the ethical issues around the use of cleaner fish as a form of sea louse control in salmon farming. We considered the situation from the point of view of the cleaner fish and the salmon, but also considered the wild populations of each species. We used an ethical matrix that considers welfare, freedom, flourishing and fairness to guide our thinking but here we present a summary of the issues.

Ethical issues:

The welfare of the salmon vs. the welfare of the cleaner fish
The farming and use of a species (cleaner fish) to improve the health, welfare and productivity of another species (Atlantic salmon) is almost unique in food animal production. The interviewed NGOs were all concerned about the welfare of cleaner fish in a system where the welfare of the salmon will be very likely prioritised over the welfare of the cleaner fish. There is a concern that, although there are costs associated with the purchase and maintenance of the cleaner fish, they are not the final saleable product of the salmon farms, so their welfare is not considered as high a priority by the salmon companies. Most companies have dedicated cleaner fish managers, who have responsibility for the cleaner fish, and there are codes of practice and welfare standards specifically for the cleaner fish, but the ultimate priority likely lies with the salmon. Some NGOs would prefer that cleaner fish were not used at all in salmon production, but recognised that until another reliable method of sea louse control is found, the use of cleaner fish is important for the

welfare of the salmon and for having a limited impact on the environment around the sea pens.

Welfare benefits for the salmon

In most cases, the salmon benefit from the presence of the cleaner fish, as their activity reduces the level of infestation of sea lice. A lower parasite burden also means that the salmon have better immune function and are more resistant to other diseases. The use of cleaner fish reduces the need for more aversive treatments such as chemotherapeutics and thermal delousing treatments, which are stressful for the salmon, and may be associated with higher mortality.

Life in the wild vs. life in captivity for cleaner fish

Compared with free-living ballan wrasses and lumpfish, cleaner fish that are reared in hatcheries and deployed onto salmon sites experience a less enriched and varied physical and social environment. However, they may experience less hunger, predation, disease, parasitism and fear (of predators, etc.). Hatchery-reared fish are vaccinated, but disease pressure may be high in salmon farms, depending on the level of biosecurity, presence of vectors in the environment and management factors.

Effects on the wild population of cleaner fish

It is possible that there may be adverse effects of the removal of eggs, juvenile or mature fish on the wild populations of cleaner fish. The wild population may become less viable because of a reduction in numbers. Likewise, if numbers are reduced, the opportunity for protection against predators provided by a larger school of fish is reduced. Additionally, the sequential hermaphroditic nature of ballan wrasse, with females transitioning to males after 6 to 7 years, and males only making up 8-12% of the overall population (Pritchard et al., 2025b) means that avoiding catching these males is important for the sustainability of the population. Encouragingly, a recent study assessing data from Scottish fish landings data showed that no ballan wrasse males were caught (only one fish likely in transition), but 4.4% of fish caught were outside the size limits imposed. However, there are no data on population sizes or trends to allow us to assess the effect of fishing on the wild populations.

Effects on the wild population of salmon and other wild fish species

The wild salmon population may benefit from the presence of cleaner fish within the sea pens. If the number of sea lice within the pens is reduced, there are likely to be fewer lice moving from the sea pens into the surrounding seawater and infecting the wild salmon population. All wild fish species may benefit from the use of cleaner fish in salmon production, as there may be a reduction in the use of chemotherapeutics, which means that less of the residue reaches the wider sea environment.

However, the effects of removal of cleaner fish from the marine habitat on the parasite load of resident fish may be an issue, but there are no data to understand if there is any effect. Additionally, some species of fish caught as ‘bycatch’ during the wild-capture of ballan wrasse have potential to be vulnerable to overexploitation (Pritchard et al., 2025a), suggesting that more refined methods of capture should be implemented.

Ethical consideration of early euthanasia for cleaner fish
Ideally, the cleaner fish would be used in more than one salmon production cycle. Ethically, it seems wasteful to sacrifice healthy cleaner fish because of difficulties with biosecurity nor utilise them for some consumptive use. Some of the salmon companies are actively considering options to reduce this wastage.

6. Conclusions and recommendations

Recommendations for further research
Further research is required to determine the causes of the unexplained losses of cleaner fish. The losses may be very high and the missing animals are likely to have died and likely experienced poor welfare before death due to disease or predation. Likewise, causes of mortality should be investigated, including the impact of disease, and an investigation of the likelihood of predation or undernutrition contributing to mortality. The variation in mortality rates shown in the literature and through the discussion with industry indicates that lower rates are possible.

-As part of the endeavour to decrease losses, better records of numbers of cleaner fish put into salmon sea pens and how many are recovered from them at the end of the salmon production cycle are needed. This would aid in understanding the extent of losses and, in conjunction with other data capture, would likely help to understand factors leading to losses.

We recommend the implementation of welfare assessment protocols for cleaner fish that cover all phases of rearing and deployment, from the capture of wild wrasses, transport of all cleaner fish from point of capture or rearing facilities to the salmon farm, during any on-farm conditioning/acclimation period and during the period when they live in the salmon pen. OWIs for cleaner fish have been created by some in the industry, but they should be reviewed independently and used across the industry to allow welfare to be monitored at all life stages. The RSPCA guidelines could be strengthened to include OWIs. There should also be action plans in place for when welfare compromises are identified.

-Further research should be carried out into management including acclimation conditions, rearing conditions and the best methods to encourage foraging on sea lice to improve effectiveness and therefore reduce the number of cleaner fish required.

-Further research is needed to develop methods for effectively removing cleaner fish before salmon treatment to reduce stress and mortality in the cleaner fish during these procedures.

-Research into effective health treatments specifically for diseases affecting cleaner fish is needed. Likewise, the development of species-specific slaughter methods for all cleaner fish and handling methods for lumpfish are needed.

-The environmental and social needs of cleaner fish during captive breeding and rearing and how these affect their efficacy in sea louse removal are still not fully understood. There is much more that could be done to understand the environmental enrichment needs of the cleaner fish during their lifetimes, from the captive breeding and rearing phases and through into their use in the salmon sea pens.

Overall recommendations and conclusions

In recognition of the impact of cleaner fish on salmon welfare and potential benefits for wild fish stocks of a reduction in sea louse numbers, we do not currently recommend any changes to the practice of using cleaner fish in salmon farming in Scotland.

However, we do recommend that further research is conducted into the welfare of cleaner fish, including, in particular better record keeping around the losses of animals in sea pens, and action to improve survival.

Further, we would recommend that alternatives to the use of cleaner fish for sea louse control are explored, with the aim of phasing out the use of cleaner fish once sustainable alternatives are in place, and preferably within the next ten years.

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8. Glossary

Crowding – the term crowding refers to the gathering of fish from a larger pen into a smaller space. This typically occurs before a treatment, transport or slaughter (Noble et al., 2018).

Thermal delousing systems – the use of a thermolicer involves crowding the fish before pumping them through a bath of hot water of up to 34°C (Overton et al., 2019). The warm water is If the water is above 28°C, the fish show signs of pain (Nilsson et al., 2019).

Physical or mechanical delousing systems – these delousing treatments involve the fish being crowded and then pumped through a system where lice are removed using low pressure water sprays or turbulence (Overton et al., 2019).

Appendix I – Membership of the Scottish Animal Welfare Commission

The Scottish Animal Welfare Commission Members are:

- Professor Cathy Dwyer from Scotland's Rural College and the University of Edinburgh (Chair)
- Dr Harvey Carruthers, veterinary surgeon
- Mike Radford, lawyer specialising in Animal Welfare
- Paula Boyden, Veterinary Director at Dogs Trust
- Professor Marie Haskell, Professor in Animal Welfare Science at Scotland's Rural College
- Dr James Yeates, Chief Executive Officer of the World Federation for Animals
- Libby Anderson, Animal Welfare Policy Advisor
- Mike Flynn, Retired Chief Superintendent at the Scottish SPCA
- Dr Pete Goddard, veterinary surgeon
- Professor Andrew Kitchener, Principal Curator of Vertebrates at National Museums Scotland
- Dr Ellie Wigham, Lecturer in Veterinary Public Health, University of Glasgow

Scottish Animal Welfare Commission: member biographies.

Appendix II – Acknowledgments

The following individuals gave verbal evidence to SAWC in the preparation of this report: representatives of Bakkafrost, Compassion in World Farming, Loch Duart Salmon, OneKind, Otter Ferry Sea Fish, MOWI, RSPCA, SalmonScotland, Scottish Sea Farms.

Appendix III – Contact Details

The Commission is contactable through the Scottish Government's Secretariat Support:

Secretariat Support for the Scottish Animal Welfare Commission
P-Spur
Saughton House
Edinburgh
EH11 3XD
Email: SAWC.Secretariat@gov.scot

Appendix IV - Biology of lumpfish

Lumpfish or lumpsucker, *Cyclopterus lumpus* L.

Family Cyclopteridae, Superfamily Cottoidea, Order Scorpaeniformes.

IUCN List status: Near Threatened

Most of this account is based on Davenport (1985) and Powell et al. (2018).

Description

The lumpfish has a globular body shape and gets one of its names from the modified pectoral fins which form a sucker, which is used to attach the lumpfish to rocks and other surfaces subject to forceful currents. The sucking disc is round, broad and muscular and occupies c.20% of the body length and generates as pressure of -1.0 kPa with an estimated suction efficiency of 95.8%, which is probably enhanced by mucus in addition to the sucker anatomy (Davenport and Thorsteinsson 2011). It takes 98.3-101.6 kNm^{-2} force to dislodge the sucker (Davenport and Thorsteinsson 2011).

The body is roughly twice as long as it is deep. There are three lateral ridges running along each side of the body, which are marked with tubercles and which are most obvious on the dorsal ridge. The body is roughly triangular in cross section with a flattish ventral surface. The head is short with moderate lateral-facing eyes, slit-like opercula, a blunt snout with an upturned mouth with small teeth. The first dorsal fin is covered in thick skin which forms a long high crest with large compressed tubercles anteriorly and dorsally. The crest height and number of tubercles increases with age. Size, skin texture and coloration are sexually dimorphic. Males are c. 30 cm long and are red, orange or purple, eyes, and ventrum in spawning season. Females are c.42 cm long and are grey or blue-green. Lumpfish can alter their coloration in minutes to match that of algae. Light intensity and photoperiod are both important in colour matching to help avoid predators through crypsis.

Lumpfish do not have a swim bladder. Females are neutrally buoyant owing to extensive subcutaneous jelly, low-osmolarity ovarian fluid and a loos-fibred dorsal musculature which contains much water. Males are also neutrally buoyant owing to a body lipid content.

Distribution

The lumpfish’s wide distribution of 32,000 km of north Atlantic Ocean coast ranges from Disko, Greenland to Chesapeake Bay, USA (70° – 37° N) in the west Atlantic Ocean and from Jan Mayen, Svalbard, White and Barents Seas to southern Portugal in the east Atlantic. It is most abundant around the southern tip of Greenland, Iceland, the Faroes and the British Isles. It is a vagrant in the Mediterranean Sea.

A recent genetic study has shown that lumpfish occur in five genetically distinct stocks: West Atlantic (USA and Canada); Mid-Atlantic (Iceland); East Atlantic (Faroes, British Isles, Norway and Denmark); English Channel; Baltic Sea (Whittaker et al. 2023). Some phenotypic differences have been observed among these stocks, but it is unclear if these differences represent phenotypic plasticity or not. For example, lumpfish in the Baltic grow slowly and mature at a small size with a higher condition factor (Whittaker et al. 2023). The effective population size is lowest in the northeast Atlantic where most of the fishery occurs.

Lumpfish occupy different habitats at different life stages. Adults are solitary and are found far offshore in water up to several hundred metres deep (bentho-pelagic). They have been recorded up to 868 metres deep, but normally occur at 50-150 metres deep. However, hatchlings, juveniles and breeding adults are found in inshore waters.

Lumpfish are hardy and are found in August sea temperatures ranging from 0 to 20^{o}C. Although they are eurythermal, they prefer colder water. They can survive in low salinity sea water in the Baltic Sea and Hudson Bay.

Female lumpfish are semi-pelagic, and migrate annually between deep water in winter to feed to shallow inshore water to breed. Lumpfish migration may occur over long distances up to more than 1000 km, with a maximum recorded distance of 1612 kn (Kennedy et al. 2024). They may return to the same area for breeding. After spawning female disperse, travelling up to 49 km/day, while males take care of the eggs (see below). Females migrate soon after spawning. A study in Norway using acoustic trackers found that the mean time for females to disperse from the fjord was three days and the maximum was seven days (Mitamura et al. 2012).

Diet and feeding

Lumpfish feed on large planktonic organisms in surface to mid-depth waters. The intestine is about twice as long as the body and there are 36-79 pyloric caecae which aid efficient digestion. Among gut contents recorded in lumpfish are small crustaceans, such as mysids, euphausiids, amphipods, isopods and decapod larvae, and also ctenophores, polychaetes, insects, small fishes and sea grasses.
The sucker allows lumpfish to feed passively or actively. Juveniles become more active a few weeks after hatching; they cling passively to substrates when food is abundant and easy to find, but they are also active foragers if food is not abundant.

Reproduction

Lumpfish return to shallow rocky waters with high tidal surges. They are dependent on their sucker to hang on to substrates owing to their low density, large surface area and weak musculature. Neither male nor female lumpfish feed during the breeding season.

The lumpfish is a determinate batch spawner which produces a maximum of two batches of similar numbers of eggs per batch (100,000-400,000) annually within the ovary (Kennedy 2018). Eggs have been recorded being laid over a period of c. four months, but they are probably able to produce them over a longer range of time (Kennedy 2018). The eggs mature over c. eight months (Kennedy 2018). Egg masses are c.26 x c.10. x c.10 cm in size and they are usually laid among stones and in kelp (*Laminaria*) beds, but not on rocky substrates. The egg masses form hard clumps in the first 48 hours after spawning due to calcium and magnesium ions in the ovarian fluid. Eggs have been recorded as 2.2-3.0 mm (Davenport 1985) or

2.05-2.50 mm in diameter and larger fish produce larger eggs (Kennedy 2018); the eggs from the first egg batch.

Adult lumpfish are culled to extract eggs and milt for rearing in captivity.

Males establish territories in shallow water on rocky shores or weed-covered substrates early in the breeding season. Because females arrive asynchronously, this allows males to breed with several females. In Iceland, Norway and Newfoundland females come inshore during March-April and they spawn from early July until late August. Gravid females have been recorded from early January or early May in the English Channel. In controlled conditions it has been found that temperature controls sexual maturation, whereas photoperiod controls spawning (Puvanandran et al 2022, Mlingi et al. 2024). Manipulation of these factors in captivity can compress an annual photoperiod cycle into nine months (Puvanandran et al 2022, Mlingi et al. 2024).

External fertilisation of the eggs occurs at the nest site and lasts 5-10 seconds. As the eggs adhere into ovoid mass, they are fertilised immediately by the male, who may mould the eggs into the nest before the mass hardens. Males create funnel-like depressions in the egg mass to facilitate gaseous exchange and removal of nitrogenous waste. Older lumpfish may not recover from spawning.

Males brood the egg mass for 6-10 weeks and spend up to 99% of their time caring for and defending egg masses under favourable conditions (optimal currents and few predators) but this was reduced to 55% under unfavourable conditions (Zuyev and Rusyaev 2023). They aerate the eggs by puffing water from the mouth for up to one hour at a time and they may show signs of tiredness after long periods of aerating the egg mass (Zuyev and Rusyaev 2023). Males have also been observed fanning the egg mass with their pectoral fins and even the dorsal and caudal fins. Most aeration has been observed after the eggs have been fertilised and before the hatchlings emerge In shallow water males spit or may lie on one side with an exposed operculum in order to squirt water over the egg mass. Males may care for and defend more than one egg mass during a breeding season.

Males may remove or protect egg masses from conspecifics and predators, e.g., crabs, periwinkles, whelks, starfishes, sea urchins and fishes, such as cod and pollack (Zuyev and Rusyaev 2023). They attack fishes but may try to hide from or retreat from larger predators.

Hatchlings are 5-6 mm long and survive at first from a yolk sac and then feed on harpacticoid copepods and halactrid mites, before moving on to more active amphipods and decapod larvae. Hatchlings and juveniles, ranging 5-55 mm long, are year-round seaweed specialists, but juveniles may occur in rock pools. They feed on surface plankton after hatching and switch to algal invertebrates when larger.
Eggs develop more rapidly in warmer water. Min T 3.8 C; hatch after 40 days at 5 C and 25 days at 9.8 C. Hatch at night, 20-30 days at 10 C, ovr a period of 7-10 days.

The development of the juveniles from hatching takes 70 days in the North Sea at the start of the breeding season, but this reduces to 14 days later. Therefore eggs develop more rapidly in warmer water; at 5 °C they hatch after 40 days and at 9.8 °C they hatch after 25 days. Development in the White Sea has been recorded to take up to two months. They mainly hatch at night over a period of 7-10 days.

The suckers of hatchlings are functional from hatching and they may even stick to the male parent.

Males mature earlier, but females live longer. Spawning adults are at least four years old, but mostly range from 5-7 up to 9-10 years old. In the North Sea adults mature 1-2 years earlier. Based on otoliths in the North Sea, Iceland, Norway and Greenland, males may breed at 2-3 years old and females at 3-4 years old.

Lumpfish predators include sharks, seals and sperm whales. Males may be taken by gulls, sea eagles and otters in shallow water. Females are positively buoyant after spawning and more vulnerable to predation. The largest lumpfish weighed 9.5 kg, was 70 cm long and 14 years old.

Appendix V - Biology of ballan wrasse

Ballan wrasse, Labrus bergylta Ascanius

Family Labridae, Superfamily Perciformes, Order Labriformes,

IUCN List status: Least Concern

This account is based largely on Davie et al. (2018).

Description

The Ballan wrasse has a heavy body with a large head and thick fleshy lips (Baldock and Dipper 2023). It has a single dorsal fin that runs along the body with sharp spines in the anterior part, which is usually folded close to the body. Coloration is variable ranging from mottled brown or green to reddish with a pale underside and pale spots on the fins (Baldock and Dipper 2023). The large scales have a dark edge and pale centre, which can give some fish a spotted appearance when this scale coloration is highly contrasting. There is no difference in coloration between the sexes, although larger fish tend to be males. Young fish tend to be uniform in coloration, mainly green, reddish or beige. Ballan wrasses reach up to 65 cm long, but typically they are 30-40 cm long (Baldock and Dipper 2023).
The two colour morphs and the two sexes display divergent growth curves (Villegas-Rios et al. 2013b). Males and spotted individuals reach larger mean asymptotic lengths than females and plain individuals, respectively, but grow more slowly to reach their asymptotic length. Almada et al. (2016) found no genetic differences (mtDNA and nuclear markers) between spotted and plain morphs, but Quintela et al. (2016) suggested that these two colour morphs may represent two distinct species based on 20 microsatellites. More recently, Seljestad et al. (2020) found distinct genetic differences (82 SNPs) between sympatric spotted and plain morphs in Galicia, northwest Spain, but not in Scandinavia, suggesting a more complex pattern of differentiation.

Distribution and habitat

The Ballan wrasse is found in coastal waters of the eastern Atlantic ranging from Morocco to Norway (Davie et al. 2018). Genetic analyses of mtDNA and microsatellites have identified two main genetic clades (Atlantic and Scandinavian), which probably reflect glacial refugia in the North Sea and off the western and southern Iberian coasts with an additional clade from a largely isolated refugium around the Azores (D'Arcy et al. 2013a; Almada et al. 2017). The current population structure has its origins in glacial refugia coupled with current and past oceanographic circulation patterns.

The Ballan wrasse inhabits sublittoral zones and is closely associated with rock faces, boulder slopes, offshore reefs and kelp beds up to 30 m deep (Davie et al. 2023, Burns et al. 2025). It is active only during the day, hiding in rock crevices and seaweed beds at night (Davie et al. 2018).
Ballan wrasses have very small home ranges and show high site fidelity. A study of home-range use by Ballan wrasses in the Galician Atlantic Islands Maritime-Terrestrial National Park based on 25 individuals over 71 days between September

and November 2011 showed that they stayed within the monitored area 92% of the monitored time (Villegas-Rios et al. 2013b). Home ranges were very small; mean total minimum convex polygons were estimated as 0.133 ± 0.072 km2 and whereas 95% kernel distribution estimated mean home-range size as 0.091 ± 0.031 km2 (Villegas-Rios et al. 2013b). The mean core area (50% kernel) was very small: 0.019 ± 0.006 km2. Ballan wrasses showed different daily movement patterns, with most fish (92%) being more active and moving greater distances during daytime. Most fish (76%) had larger home ranges during the day compared with the night during the night and there was high site fidelity (volume of intersection index between consecutive daily home ranges was 0.75 ± 0.13) (Villegas-Rios et al. 2013b). Ballan wrasses are generally inactive at low seawater temperatures of 5-10°C (Yuen et al. 2019).

Diet and feeding

Ballan wrasses have a short gut and are agastric, and so need to feed continuously. Deady and Fives (1995) investigated the gut contents of 99 Ballan wrasses between April and July from Galway Bay, Ireland and 95 individuals between April and June from Brittany, France. Galway Bay Ballan wrasses' diet included 19 food categories. Decapods (Cancer pagurus, Carcinus maenas and Eupagurus bernhardus) and bivalves (c.90% Mytilus edulis) were the major prey categories in both areas, but algae (Laminaria spp., Fucus spp., Ceramium rubrum and Palmaria palmata) and gastropods (Littorina spp., Calliostoma zizyphinum, Bittium reticulatum and Lacuna vincta) were eaten often but in much smaller amounts. Although the volume of major food categories did not vary significantly with fish length, wrasses more than 20 cm long ate greater volumes of bivalves than smaller fish. Dietary diversity increased during the breeding season. The Ballan wrasses from Brittany mainly ate bivalves with Chlamys spp.(c.80%) comprising most of these (Deady and Fives 1995).

There were some differences in diet between the same sexes at the two different locations. Males ate many more bivalves and preferred fish slightly more than females, but females had a more diverse diet than males, consuming more algae, amphipods, isopods and considerably more bryozoans (Deady ad Fives 1995). The males from Brittany ate fewer bivalves and more ascidians, decapods and fish than females, but dietary diversity was similar for both sexes (Deady and Fives 1995). The diets of males from each site had different diets; the males from Brittany ate more algae, ascidians and fish and fewer bivalves compared with the Galway Bay population. Females from Galway Bay consumed significantly more decapods and amphipods, whereas females from Brittany ate more ascidians and bivalves.

Cardona et al. (2020) used stable isotope analysis to compare the isotope niches of the plain and spotted morphs of the Ballan wrasse off Galicia (NW Spain). Plain morphs of Ballan wrasse always had depleted δ13C values compared to spotted morphs, whereas δ15N values of plain morphs showed that they fed at higher trophic levels than the spotted morphs in high-density unfished populations, but these differences were not apparent or were reversed in fished areas. Therefore, resource partitioning is density dependent and the two morphs have different ecological niches in unfished ecosystems (Cardrona et al. 2020).

Le et al. (2019) have described the digestion, absorption and evacuation rates of captive juvenile Ballan wrasse fed dry or pre-soaked diets with inert markers. Evacuation of the digestive tract was completed by 12-14 hours after feeding for both kinds of dietary hydration. Ninety percent of the digesta moved from the foregut to the midgut after 4-8 hours and 7% was found in the hindgut after four hours. The major site of digestion was the foregut, where most carbohydrates (86%), proteins (74%), and lipids (50%) were absorbed (Le et al. 2019). Absorption of proteins (90%), carbohydrates (98%) and lipids (80%) increased until the hindgut.

Reproduction

The Ballan wrasse is a monandric protogynous hermaphrodite with a harem mating system and a highly skewed sex ratio of c.10% males in the wild (Grant et al. 2016). All Ballan wrasses hatch as females and protogynous sex change of some females to males is thought to driven by mostly unknown social cues (possibly size and/or social dominance) from about 5-6 years old and when they are more than 28 cm long (Grant et al. 2016). In northern Europe 50% sex change occurs at 10.8 years with a weight of 636 g and length of 342 mm (Davie et al. 2018).

Male Ballan wrasses are highly territorial during the spawning season, defending areas of up to 300 m2, which is a small proportion of the estimated home-range size (see above) (Davie et al.2018). The males guard active nest sites, which restricts the spawning season. It has been suggested that there is a latitudinal cline in spawning season, but this has not been confirmed (Davie et al. 2018).

Based on histology, Ballan wrasses are classified as a group-synchronous multiple-batch spawning species, with the breeding season occurring between April and July (mean 58.5±4.8 days) and varying geographically (Muncaster et al., 2013). In captivity there are 3-5 spawning periods, lasting 1-6 days including spawning, with an inter-spawning interval 8-15 days and 4-6 spawning windows over the season. This regular pattern of spawning suggests a “multiple or repetitive spawning” reproductive strategy (Grant et al. 2016).

Fertilisation rates are very high in captivity (>87.5%), but hatch rates are very variable (0-97.5%), peaking in the middle of the spawning season. A captive study showed that 50% of six spawnings involved single parents, while the other 50% involved more than a pair of parents, including a male with two females and a female with fertilisations by two males (Grant et al. 2016). D’Arcy et al. (2012) identified eight primary embryonic developmental stages of the eggs. Ballan wrasses have a short egg stage, hatching occurring c.123 hours (or 62.5 degree days) after fertilisation at 12.2±1.1oC; the larvae swim intermittently near the surface of the water column (D’Arcy et al. 2012). Young fish grow fastest and are more robust and active in the winter. Larval growth factors have been studied by Piccinetti et al. (2017) and larval organ growth in captivity by Gaagnat et al. (2016). Ballan wrasses grow slowly and are long-lived, reaching a maximum length of 65.9 cm and weight of 4.35 kg during a 29-year lifespan (Davie et al. 2023).The oldest known Ballan wrasse was a 34-year-old female caught off the coast of western Norway (Pritchard et al. 2024).

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Appendix VI – Lifecycle of the sea louse *Lepeoptheirus salmonis.*

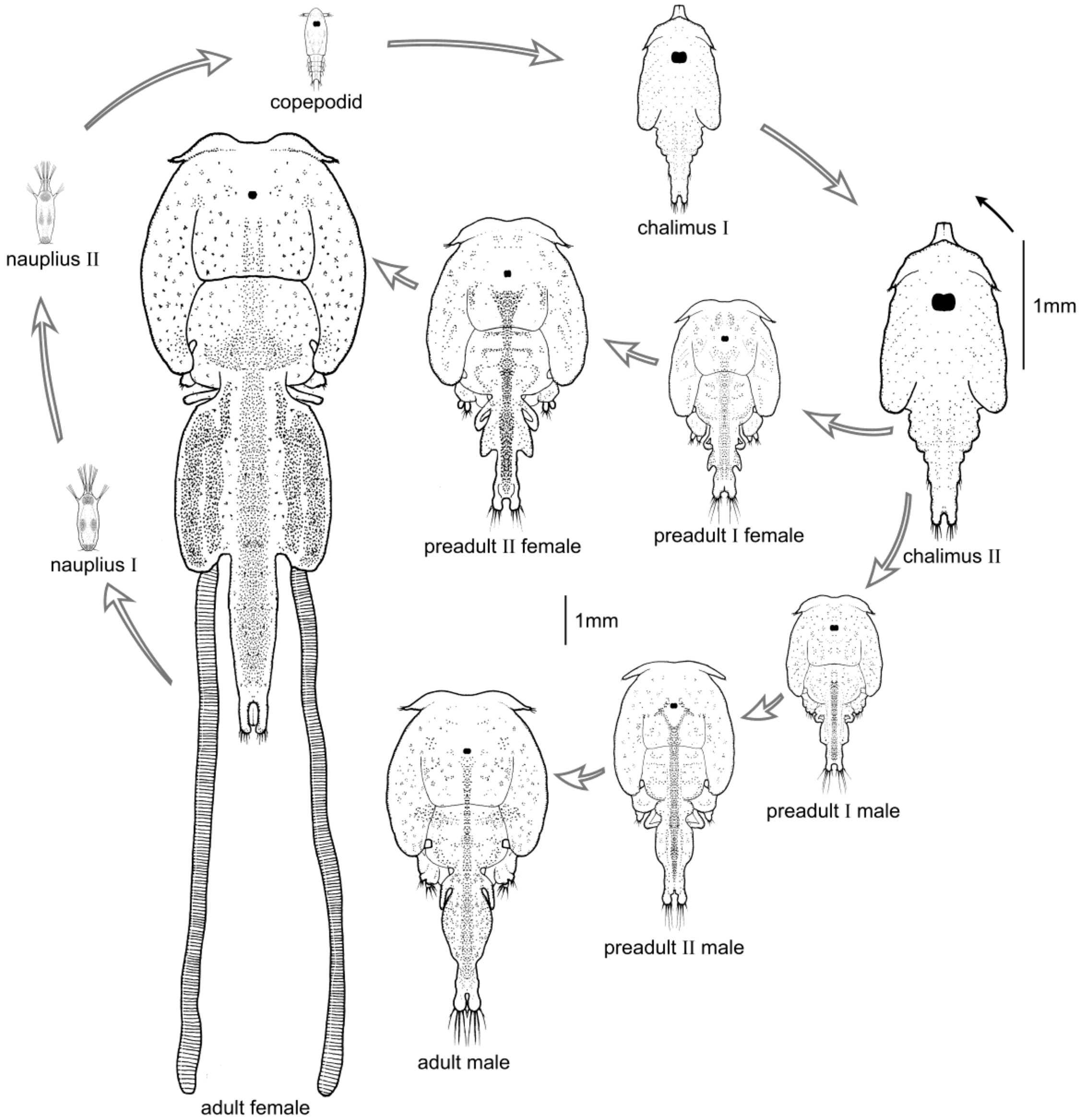

Diagram 1. The diagram shows the life stages of *Lepeoptheirus salmonis*. It shows that the male and female salmon lice cannot be distinguished by the naked eye in the nauplius, copepodid and chalimus stages. Sex determination by visual inspection is possible from the first pre-adult stage.

Barrett et al., (2020) state that chemical delousing (in-feed or bath) and fresh or brackish water delousing are effective again the larval stages (nauplii and copepodids), sessile stages (chalimus I and II) and mobile stages (pre-adult and adult). Physical and thermal delousing treatments are used for the sessile and mobile stages, while cleaner fish are used only for the mobile stages.

Sea Lice Research Centre (University of Bergen) 2020, "SLRC - Life cycle of the salmon louse (Lepeophtheirus salmonis)", DataverseNO. Creative Commons CC0 1.0 Universal Public Domain Dedication.

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The Scottish Government
St Andrew's House
Edinburgh
EH1 3DG

ISBN: 978-1-80643-362-9 (web only)

Published by The Scottish Government, November 2025

Produced for The Scottish Government by APS Group Scotland, 21 Tennant Street, Edinburgh EH6 5NA
PPDAS1669786 (11/25)