Recommendation on using ethology, an understanding of fish behaviour, to improve fish welfare and production

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I. Background

This paper is developed from the AAC report *Using Ethology to Improve Farmed Fish Welfare and Production* (accessible from https://aac-europe.org/en/recommendations/reports/459-using-ethology-to-improve-farmed-fish-welfare-and-production), published in 2022, which has detailed scientific references. This report also referenced the FishEthobase website (accessible from https://FishEthoBase.net/), which details welfare profiles for a range of farmed fish species including the five main European ones considered in this document: Atlantic salmon, rainbow trout, gilthead seabream, European seabass and common carp. For a more detailed account of the benefits of environmental enrichment, see Arechavala-Lopez et al (2022a[1]).

II. Fish welfare

The welfare of fish in aquaculture is considered increasingly important both for the fish being farmed and for seafood production. In our survey of fish farmers, 83% gave very high importance to welfare, 70% considering it highly important for production.

There are many valid descriptions and definitions of animal welfare which apply to fish, but for the purposes of this paper we shall combine the three approaches discussed in Fraser, 2009[2]. These approaches define welfare separately as:

1. A function-based approach where the animal is in a good physical state, for example in good body condition and free from disease and injury.

2. A nature-based approach, where the animal is able to develop and live in ways which are natural for the species, generally able to make choices based on their inner motivations.

3. A feelings-based approach, where the animal is in a good mental state, minimising suffering whilst maximising positive emotions or pleasures.

A useful insight of another approach to animal welfare – the "five domains" – is that the mental state is the final welfare outcome of the other inputs, in this case nutrition, environment, health and behaviour (Mellor *et al*, 2020[3]). However, it is clear that all these

[1] Arechavala-Lopez, P., Cabrera-Álvarez, M.J., Maia, C.M. and Saraiva, J.L., 2022. Environmental enrichment in fish aquaculture: A review of fundamental and practical aspects. *Reviews in Aquaculture*, *14*(2), pp.704-728. https://ccmar.ualg.pt/sites/ccmar.ualg.pt/files/arechavala-lopezetal_2021_reviewee.pdf

[2] Fraser, D., 2009. Assessing animal welfare: different philosophies, different scientific approaches. Zoo Biology 28, 507–518. https://doi.org/10.1002/zoo.20253

[3] Mellor, D.J., Beausoleil, N.J., Littlewood, K.E., McLean, A.N., McGreevy, P.D., Jones, B. and Wilkins, C., 2020. The 2020 five domains model: Including human–animal interactions in assessments of animal welfare. *Animals*, *10*(10), p.1870.

aspects interact. An animal in a good mental state is likely to make good natural choices which benefits their physical condition and therefore production.

For the purposes of this recommendation, we are concentrating on understanding the nature-based approach and how it impacts the fish's physical and mental welfare.

III. Ethology

Ethology is the science of animal behaviour. It has many practical applications for fish farming

1. In the development of operational welfare indicators to determine and improve welfare and production.

2. In determining the behavioural requirements of each fish species.

3. In helping to determine the suitability of any species of fish for systems in which they may be kept.

IV. Determining the behavioural requirements of a species

Ethology asks four questions about any animal behaviour[4]:

1. What is the function of the behaviour?
2. How did it evolve?
3. What causes the behaviour (what is the trigger?)
4. How does it develop over the lifetime of the animal?

It is considered that the starting point for understanding the behavioural needs of a species is the natural behaviour in the wild. This is controlled by highly motivated natural instincts which have evolved to ensure the survival of the species in its natural environment over time. Whilst some behaviours may have been modified by artificial selection, it must be noted that in the case of fish this has been carried out for relatively few generations, that most selection is aimed at production rather than behaviour traits and that in land animals inherited behaviours such as nest building, though not of value to the farmer, remain highly motivated in pigs and hens despite a great many generations of selective breeding. It should therefore be assumed that wild behaviours remain motivated unless there is strong evidence to the contrary.

To understand why being able to perform a natural behaviour is important for the welfare of a fish, we need understand the function of the behaviour for the fish. We also need to

[4] Bateson, P., Laland, K.N., 2013. Tinbergen's four questions: an appreciation and an update. Trends in Ecology & Evolution 28, 712–718. https://doi.org/10.1016/j.tree.2013.09.013

understand what triggers the behaviour. For example, high or low temperature or the presence of poor water quality may motivate the fish to swim away or, in extreme cases, to trigger escape behaviours. The function of the behaviour is to protect the fish from the impacts of poor water quality; the trigger would be the direct effect of sensing the change in temperature or water quality parameter.

The frustration of such behaviour is likely to cause poor welfare in addition to any injury the fish will suffer directly from the adverse conditions; for example, a seabream may suffer immediately from a sensation of being cold in addition to going on to develop winter sickness. The behaviour in this case is entirely dependent on environmental conditions – if the temperature and water quality is conducive to the fish, no welfare problem will emerge.

Other behaviours such as migration, which may also be triggered partly by environmental factors, may also be internally driven at certain stages of fish development. Frustration of such behaviours may cause poor welfare even if the behaviour no longer serves a function in the fish farm. An understanding of the triggers for such behaviours is required to analyse the welfare impact of their frustration.

Species vary in their behavioural needs. Some species use shelter at various stages in their lifecycle. European seabass[5], common carp[6] and rainbow trout[7] are commonly found amongst plants or other objects at all ages. Trout[8] also seek shelter amongst boulders, stones and woody debris. Juvenile seabass readily seek shelter when provided. Failure to provide shelter risks causing stress.

Some species also use substrate as part of their natural behaviour and carp[9] and seabream[10] are commonly found above sandy or muddy bottoms where they may forage. Adult seabreams are suspected of burying themselves at night in the sand[11].

In the wild, most fish species have large home ranges. Common carp, adapted to life in lakes and rivers, still swim over an area of 30,000 m² or more[12]. Marine species commonly range much farther than this. Most species farmed are generally found in the top 3 or 5 metres of the water but can swim to much greater depths: 70m for European seabass[13], 100 m for

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[5] Fishethobase European seabass overview findings - https://fair-fish-database.net/db/14/farm/findings/#bibl_SZC6FPDT .
[6] Fishethobase common carp overview findings https://fair-fish-database.net/db/12/farm/findings/#bibl_BGTSPSDG.
[7] Fishethobase rainbow trout overview findings https://fair-fish-database.net/db/30/farm/findings/#bibl_P9C8GL9G.
[8] Fishethobase rainbow trout overview findings *op cit.*
[9] Fshethobase common carp overview findings *op cit.*
[10] Fishethobase gilthead seabream overview findings https://fair-fish-database.net/db/49/farm/findings/#bibl_FA56HGK6.
[11] Abecasis, David, and Karim Erzini. 2008. Site fidelity and movements of gilthead sea bream (Sparus aurata) in a coastal lagoon (Ria Formosa, Portugal). Estuarine, Coastal and Shelf Science 79: 758–763. https://doi.org/10.1016/j.ecss.2008.06.019.
[12] Fishethobase common carp overview findings *op cit.*
[13] Fishethobase European seabass overview findings op cit.

rainbow trout[14] and 150m for Gilthead seabream[15]. Species may also swim to deeper depths in winter, for example common carp[16], perhaps since the temperature will vary less.

Many fish migrate between different ranges, Atlantic salmon famously migrating over thousands of miles[17]. Seabream migrate to coasts, lagoons and estuaries in the spring and back out to sea in the winter[18]. Given the tendency of this species to suffer from winter sickness, it may be speculated that outward migration may be partly motivated by a need to reach milder winter temperatures at sea.

Most of the main species kept in European aquaculture school at times for security but also have solitary phases when they may be territorial and aggressive towards each other[19]. High stocking densities may cause stress, though low densities may also result in aggression when they facilitate the more dominant fish to develop territories.

There is a need for more knowledge to understand the needs of the main species farmed in the EU (seabass, seabream, rainbow trout, Atlantic salmon and common carp) in relation to motivation for territoriality vs schooling and for the size of natural ranges and for the first four in relation to the drivers of migration.

It must be noted that wild fish will also be constrained in their ability to make choices, for example due to the varied availability of food or the presence of natural predators. Certain behavioural needs, for example the provision of opportunities for foraging, though not necessarily for varied foraging, can be well provided in the farming situation. Similarly, aquacultural systems may be able to exclude predators.

The provision for other needs may be more challenging. On a precautionary basis, there is a case for providing more rather than less home range and depth. Requirements for shelter and bottom substrate should be considered, depending on species and production method. Species which are solitary or aggressively territorial, at some stage in their life-cycle, may not be suitable for intensive kinds of farming.

Whilst it has been argued that artificial selection is unlikely to change basic behavioural requirements, we should be alert to the risk that it may have unintended consequences. Selection for faster growth or better feed conversion may unintentionally also select for aggressiveness and other traits which can be harmful to welfare. Some breeding practices,

[14] James, G. D., and J. R. M. Kelso. 1995. Movements and habitat preference of adult rainbow trout (Oncorhynchus mykiss) in a New Zealand montane lake. New Zealand Journal of Marine and Freshwater Research 29: 493–503. https://doi.org/10.1080/00288330.1995.9516682

[15] Bauchot, M.-L., J.-C. Hureau, and J. C. Miguel. 1981. Sparidae. In FAO species identification sheets for fishery purposes. Eastern Central Atlantic., ed. W. Fischer, G. Bianchi, and W. B. Scott. Vol. 4. Rome: FAO. https://www.fao.org/figis/pdf/fishery/species/2384/en?title=FAO%20Fisheries%20%26amp%3B%20Aquaculture%20-%20Aquatic%20species .

[16] Fishethobase common carp overview findings *op cit.*

[17] Dadswell, M.J., Spares, A.D., Reader, J.M. and Stokesbury, M.J.W., 2010. The North Atlantic subpolar gyre and the marine migration of Atlantic salmon Salmo salar: The 'Merry-Go-Round'hypothesis. Journal of Fish Biology, 77(3), pp.435-467.

[18] Fishethobase gilthead seabream overview findings *op cit.*

[19] See fishethobase profiles forAtlantic salmon, rainbow trout, European Seabass, Gilthead seabream and Common carp. https://fair-fish-database.net/.

such the production of triploid salmon, can result in higher numbers of "loser fish" which grow slowly and show abnormal behaviours[20].

V. Environmental enrichment

Some aquaculture environments lack structural environmental complexity for practical and sanitary reasons, but this may impair cognitive development in species that evolved in and are adapted to complex environments. Failure to provide for behavioural needs may also cause frustration, leading to poor welfare. There is evidence that juvenile seabream grow better and are less aggressive in the presence of a suitable gravel substrate[21] and also that increasing environmental complexity can benefit salmonids and carp[22].

The behavioural needs of fish can be better met through the addition of forms of environmental enrichment which are tailored to the natural behaviour of the species.

Physical enrichment can provide shelter, substrate and complexity in a rearing environment.

All the species commonly farmed in the EU seek shelter, and most use bottom substrate, at some point in their lives[23]. The addition of structures such as hanging ropes, plastic tubes and shredding can provide structure. The addition of stones, sand and gravel can provide for the needs of benthic species. Adding hatching mats has proved to be beneficial for salmonid species[24].

Sensory stimuli may also be beneficial through increasing the complexity of experience. These include visual, auditory, chemical and tactile stimuli. For example, the environment may contain variations in light levels. However, fish should also be protected from excessive noise or continuous light – some species are active in the dark, not the light.

Occupational stimuli such as the provision of currents can also keep the fish active. Air bubbles can also provide interest and perhaps cause fish to exhibit positive play behaviour[25].

Social interaction can be positive or negative for fish. Schooling can provide protection, but solitary fish can become aggressive towards each other when exhibiting territoriality.

[20] Madaro, A., Kjøglum, S., Hansen, T., Fjelldal, P.G. and Stien, L.H., 2022. A comparison of triploid and diploid Atlantic salmon (Salmo salar) performance and welfare under commercial farming conditions in Norway. *Journal of Applied Aquaculture*, *34*(4), pp.1021-1035.

[21] Batzina, Alkisti, and Nafsika Karakatsouli. 2012. The presence of substrate as a means of environmental enrichment in intensively reared gilthead seabream Sparus aurata: Growth and behavioral effects. Aquaculture 370–371: 54–60. https://doi.org/10.1016/j.aquaculture.2012.10.005.

[22] Arechavala-Lopez, P., Cabrera-Álvarez, M.J., Maia, C.M. and Saraiva, J.L., 2022. Environmental enrichment in fish aquaculture: A review of fundamental and practical aspects. *Reviews in Aquaculture*, *14*(2), pp.704-728.

[23] See fishethobase profiles forAtlantic salmon, rainbow trout, European Seabass, Gilthead seabream and Common carp. https://fair-fish-database.net/.

[24] Arechavala-Lopez *et al*, 2022 *op cit*.

[25] Arechavala-Lopez *et al*, 2022 *op cit*.

Foraging is a strongly motivated behaviour, so dietary enrichment involving a range of feed types and feeding strategies is another means of increasing positive welfare in fish[26].

Different species have different behavioural requirements, so environmental enrichment should always be species-specific. It needs to be designed to be practicable and to avoid behavioural, biosecurity and hygiene issues. Results of enrichment need to be validated to ensure that the intended benefits are achieved.

Environmental enrichment is likely to become increasingly important as a part of aquaculture standards. It should be noted that in our survey of producers, provision of enrichment ranked highest in a list of actions for improving welfare.

The AAC report *Using Ethology to Improve Farmed Fish Welfare and Production* which this recommendation is based on has a much more detailed account of the benefits of environmental enrichment. See also Arechavala-Lopez et al (2022a) for a much more detailed and fully-referenced account.

VI. Choice of systems

Extensive systems have the potential to meet more of the natural behaviour requirements of fish including provision of shelter and substrate, and to provide for more natural stocking densities. They can provide the home ranges for species such as carp which are adapted to more confined conditions, though not for wide ranging and migratory marine species. The natural diet may be more varied. Stressful handling procedures such as grading may not be needed.

Raceways can provide natural currents. They lack depth and may be limited in home range. They may be lack environmental complexity, but enrichment such as substrates and shelters could be provided.

Cage systems provide some aspects of the natural environment including access to currents, natural light and dark patterns and may allow for some depth. Range will depend on the size of the cage, but this can be restricted. It may be harder to provide for needs such as shelter and substrate and to allow fish to escape poor water quality, extremes of heat and cold, algal blooms and jellyfish swarms. Build-up of disease and parasites can be a problem.

Intensive RAS systems can in principle control environmental parameters, though the fish are deprived of choice, are likely to be subjected to very high stocking densities and the environments are often lacking in environmental complexity.

[26] Arechavala-Lopez *et al*, 2022 *op cit*.

VII. Handling stresses

Farmed fish are exposed to stresses which they would not meet in the wild including handling, grading and vaccinating. Some of these are required to mitigate health and welfare issues inherent to intensive production.

These stresses may be reduced through the choice of less intensive systems of production and by designing handling procedures such as passive grading, the use of pumps rather than brailling, and the use of sedation and anaesthetics during transport. In our survey of producers, 61% listed steps to reduce or refine handling techniques as a measure they take to improve welfare.

VIII. Operational welfare indicators (OWIs)

When something is wrong, farmers can often quickly tell from the behaviour of the fish. In our survey of aquaculture producers, observation of fish behaviour was listed as a measure taken to assess and improve welfare; indeed, this measure had the highest score from the list given. Behaviours observed or measured included swimming and feeding behaviours and any behaviour that is abnormal in addition to physical measures such as injuries or skin and fin condition. The producers also prioritised the development of technological tools for measuring welfare such as cameras and sensors.

Frenetic behaviour at the surface could be a response to fear, lack of oxygen or other aspects of poor water quality. Disinterest in feed and a failure to feed are commonly signs of poor welfare. Conversely, exploratory behaviour and feed anticipatory activity can be a sign of positive welfare[27].

Assessing welfare through behaviour has several potential advantages if the right indicator is chosen. Behavioural observations are cheap, accessible and offer direct indications on the state of the fish that may be observed on site and in real time.

There are general behavioural patterns associated with poor welfare states (including diseases, infections, fear, pain or negative cognitive states) that are transversal to several taxa[28][29]. The neural networks underpinning these behaviours have even been recently identified[30]. The use of behavioural variables as operational indicators of negative welfare is therefore increasingly rooted on solid neurophysiological evidence, which provides ever growing reliability for their use in industry context. Although far less is known about them,

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[27] Martins, C.I.M., Galhardo, L., Noble, C., Damsgård, B., Spedicato, M.T., Zupa, W., Beauchaud, M., Kulczykowska, E., Massabuau, J.-C., Carter, T., Planellas, S.R., Kristiansen, T., 2012. Behavioural indicators of welfare in farmed fish. Fish Physiol Biochem 38, 17–41. https://doi.org/10.1007/s10695-011-9518-8

[28] Kent, S., Bluthé, R.-M., Kelley, K.W., Dantzer, R., 1992. Sickness behavior as a new target for drug development. Trends in Pharmacological Sciences 13, 24–28. https://doi.org/10.1016/0165- 6147(92)90012-U

[29] Sneddon, L.U., 2020. Can Fish Experience Pain?, in: Kristiansen, T.S., Fernö, A., Pavlidis, M.A., van de Vis, H. (Eds.), The Welfare of Fish, Animal Welfare. Springer International Publishing, Cham, pp. 229–249. https://doi.org/10.1007/978-3-030-41675-1_10

[30] Ilanges, A., Shiao, R., Shaked, J., Luo, J.-D., Yu, X., Friedman, J.M., 2022. Brainstem ADCYAP1+ neurons control multiple aspects of sickness behaviour. Nature 609, 761–771. https://doi.org/10.1038/s41586-022-05161-7

we believe that positive welfare states are a goal worth pursuing and therefore should be able to be identified and assessed.

The measurement of Operational Welfare Indicators (OWIs) formalises an experienced stockperson's observation and intuition. An OWI describes a behaviour which can be easily and effectively measured on the farm as a welfare assessment tool.

To qualify as an OWI, a behavioural measurement has to be:

1. Valid. It must clearly measure a behaviour that relates to welfare.

2. Reliable. You should get the same result whoever measures it and however they measure it.

3. Repeatable. It should be possible to get a consistent result if the measure is taken several times.

4. Comparable. It should be possible to compare the behaviour in different contexts, eg to determine the impacts of management, husbandry practices or systems.

5. Suitable. It must be practicable for use in the system or during the husbandry practice being observed.

An illustrative list of OWIs which can be used during the rearing of the five main European species (Atlantic salmon, rainbow trout, gilthead seabream, European seabass or common carp) is shown in Table III from the report which accompanies this recommendation[31][32][33][34]. Table IV from the same document, which follows it, explains how the indicators can be interpreted.

Table III- Proposed behavioural Operational Welfare Indicators (OWIs).

OWIs	rearing stage	base	level	Measurement type	Attributes	reference

[31] Marino, G., Petochi, T., Donadelli, V., Tamburrini, M., Ferrara, C., Finoia, G., Cardia, F., Padrós, F., Tort, L., Montero, D., Fabris, A., 2020. Methodology for assessing welfare in MMFF

[32] Martins, C.I.M., Galhardo, L., Noble, C., Damsgård, B., Spedicato, M.T., Zupa, W., Beauchaud, M., Kulczykowska, E., Massabuau, J.-C., Carter, T., Planellas, S.R., Kristiansen, T., 2012. Behavioural indicators of welfare in farmed fish. Fish Physiol Biochem 38, 17–41. https://doi.org/10.1007/s10695-011-9518-8

[33] Noble, C., Gismervik, K., Iversen, M.H., Kolarevic, J., Nilsson, J., Stien, L.H., Turnbull, J.F. (Eds.), 2020. Welfare Indicators for farmed Rainbow trout: tools for assessing fish welfare.

[34] Roque, A., Castanheira, M.F., Toffan, A., Arechavala-Lopez, P., Brun, E., Villarroel, M., Gisbert, E., Mylonas, C., Muniesa, A., Estevez, A., Dalmau, A., Basurco, B., 2020. Report on fish welfare and list of operational welfare indicators in sea bream. MedAid.

Aggression	broodstock, hatchery, ongrowing	animal	individual	High/low	negative (high rate=poor welfare)*	Martins et al (2012)
Exploratory activity	broodstock, hatchery, ongrowing	animal	individual	high/low	Positive (high rate= good welfare)	Martins et al (2012), Roque et al (2020)
Anticipatory activity	broodstock, hatchery, ongrowing	animal	individual	high/low	positive	Martins et al (2012)
Foraging behaviour	broodstock, hatchery, ongrowing	animal	group	high/low	positive	Martins et al (2012), Marino et al (2020)
General appetite	broodstock, hatchery, ongrowing	animal, resource	Group	high/low	positive	Noble et al (2020), Marino et al (2020), Roque et al (2020)
Group swimming behaviour	broodstock, hatchery, ongrowing	animal	Group	shoal/school/disperse	positive	Martins et al (2012), Marino et al (2020), Roque et al (2020)
Individual swimming behaviour	broodstock, hatchery, ongrowing	animal	individual	sustained/prolonged/burst/erratic	positive	Martins et al 2012, Marino et al (2020)
Stereotypical behaviours	broodstock, hatchery, ongrowing	animal	individual	yes/no or high/low	negative	Martins et al (2012), Roque et al (2020)

Surface activity	broodstock, hatchery, ongrowing	animal	Group	calm/frenetic/frenzy/fins appearing	no surface breach=good; bodies emerge=terrible	Noble et al (2020)
Thigmotaxis	hatchery	animal	individual	yes/no or high/low	negative	FishEthoBase.net, Roque et al (2020)
Use of space	broodstock, hatchery, ongrowing	resource	Group	all space used/some parts avoided; species appropriate	positive	FishEthoBase.net, Roque et al (2020)
Vacuum behaviours	broodstock, hatchery, ongrowing	animal	individual	yes/no or high/low	negative	Martins et al (2012)

Table IV – General ethogram for selected OWIs

Behaviour (OWI)	Description
Aggression	Agonistic interaction between two or more individuals. Can occur without physical engagement (i.e. Low Intensity Aggression: fin erection, colour changing, displays etc) or including physical interaction (High Intensity Aggression: chasing, biting, fighting)
Exploratory activity	Movements or actions or along the tank that apparently serve to the collection of information about new objects and unfamiliar parts of the environment.
Anticipatory activity	Movements or actions that precede the delivery of feed and indicate that the fish are aware of routine procedures taking place imminently. The most common is food anticipatory behaviour, where the fish are agitated before feeding.

Foraging behaviour	Movements or actions or along the tank that apparently indicate that fish is searching for food. Whenever the fish finds food items it eats them.
General appetite	Food anticipatory behaviour + foraging behaviour + actual eating and/or feeding.
Group swimming behaviour	Type of swimming behaviour that the group of fish is displaying: shoaling (in a group but not directional or coordinated); schooling (in a polarised, directional and coordinated swimming) or disperse (no clear group formed).
Individual swimming behaviour	General type of movement each fish is performing when swimming: regular, fast, slow, erratic bursts, balanced/unbalanced, close to surface, midwater, bottom, next to walls, etc.
Stereotypical behaviours	behavioural pattern that is abnormally repetitive, invariant and with no obvious goal or function.
Surface activity	Movement of the group of fish at the surface upon handling, cleaning or feeding procedures. Varies from calm, with only fins surfacing, to a frenzy with whole bodies surfacing or even jumping as a sign of severe stress. (Note that salmon uses surface activity to voluntarily inflate their gas bladder. This species-specific behaviour should be taken in account when using this OWI).
Thigmotaxis	Strong avoidance of open areas and preference for moving in very close proximity of the walls of the rearing environment.
Use of space	Measure of how and how much space of the rearing environment is used by the fish. Related with exploratory behaviour.
Vacuum behaviours	Actions which apparently occur in the absence of any external stimulus or disengaged from their normal elements (e.g. nest building with no substrate)
Ventilation rate	Rate at which the opercula open and close, as a measure or respiration needs of the fish.

Spawning behaviours	Movements, actions and/or displays that lead to reproduction. May include courtship, nest building, egg releasing, fertilisation, parental care or other species-specific behaviours.

OWIs should also be measured during handling, transport and slaughter. During crowding, fish should be checked for signs such as colour change, escape behaviour and air gulping. Following pumping (recommended as preferable to brailling), fish should be examined for signs of exhaustion as well as for any injuries (as example of how physical measures should be tested for as well as behavioural). During slaughter, the effectiveness of stunning should be tested using indicators such as breathing movements and eye-roll reflex (see main report for more detail).

IX. Training and knowledge transfer

All those involved in aquaculture need an understanding of fish behaviour and welfare, appropriate to the level at which they are working. All staff should understand that fish are sentient, can feel pain and be able to recognise behavioural signs of both positive and negative welfare including normal and abnormal behaviours.

Those measuring OWIs will need sufficient training to ensure that they can carry out measurements reliably. Other staff including production managers, biologists and veterinarians will need additional knowledge including the biological basis of welfare and ethology.

The more detailed AAC report which accompanies this recommendation proposes course contents which may be appropriate for different levels[35].

X. Recommendations

Recommendations for all stakeholders :

1. The natural behaviour of species which are farmed should be studied both in the wild and under farming conditions. Studies should include determining the triggers for these behaviours and the welfare consequences of behavioural frustration.

2. Appropriate methods of environmental enrichment should be assessed and developed for all species, life stages and systems in which fish are farmed.

[35] AAC, 2002. Using ethology to improve farmed fish welfare and production. https://aac-europe.org/wp-content/uploads/2023/06/AAC_ethology-and-welfare_final_with-annex.pdf

3. Operational welfare indicators (OWIs) should continue to be developed based on an understanding of fish behaviour for all species which are farmed, with priority given to the major species. There should be continuing ongoing research into the positive and negative behavioural signs of fish welfare.

4. Appropriate OWIs should be applied at all stages of the lifecycle including hatcheries, rearing, handling, transport and slaughter.

5. Guidelines for best practice should include the measurement of OWIs, the provision of environments and application of management practices which provide for the behavioural needs of fish and the choice of systems with good welfare potential.

6. Those who work in aquaculture should be trained in the natural behaviour of the species they look after and to recognise positive and negative behavioural signs of welfare. They should be trained to measure and record OWIs in a reliable and repeatable fashion. There should be support towards the training of aquaculture professionals in fish welfare and behaviour.
7. The behavioural needs of fish should be considered in the choice of systems for rearing.

8. The behavioural needs of any new species being considered for aquaculture should be studied as part of the consideration of their suitability for aquaculture.

Recommendations for the Commission :

9. The Commission, together with the Fish Reference Centre, should coordinate exchanges between aquaculture operators, scientists, and NGOs to explore and develop environmental enrichment options in aquaculture, and connect this activity to its objective in the Strategic Guidelines to map best husbandry practices including environmental enrichment.

10. The EU Animal Welfare Reference Centre for fish should give a high priority to behaviour within its work programme.

11. EU funded research projects in aquaculture should give a high priority to behaviour and welfare within their research programmes.

Recommendations for Member States :

12. Financial support should be available for measures to improve fish welfare in aquaculture, for example using EMFAF funds. This can include the development of environmental enrichment on farms, the provision of equipment such as cameras to

facilitate assessment of fish welfare, the provision of improved handling systems and humane slaughter equipment.

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