Risk Management in Aquaculture: Mooring Systems

The farming of fish in cage systems is subject to a variety of risks, including disease, predation, water quality issues and equipment failure. Equipment failure can arise during adverse environmental conditions, such as high wind velocities and heavy wave action caused during storm where cages are moored in groups by way of inter-connected mooring systems such as submerged grids. Consequently an understanding of the risks associated with mooring systems, and how best to manage those risks, is essential to successful farm management.

Any assessment of risk for a mooring system can be divided into two main parts:

1) Is the mooring system appropriate for the conditions expected at the site?
2) Is the mooring system regularly inspected and maintained to a sufficient standard to maintain its minimum design strength?

Mooring design

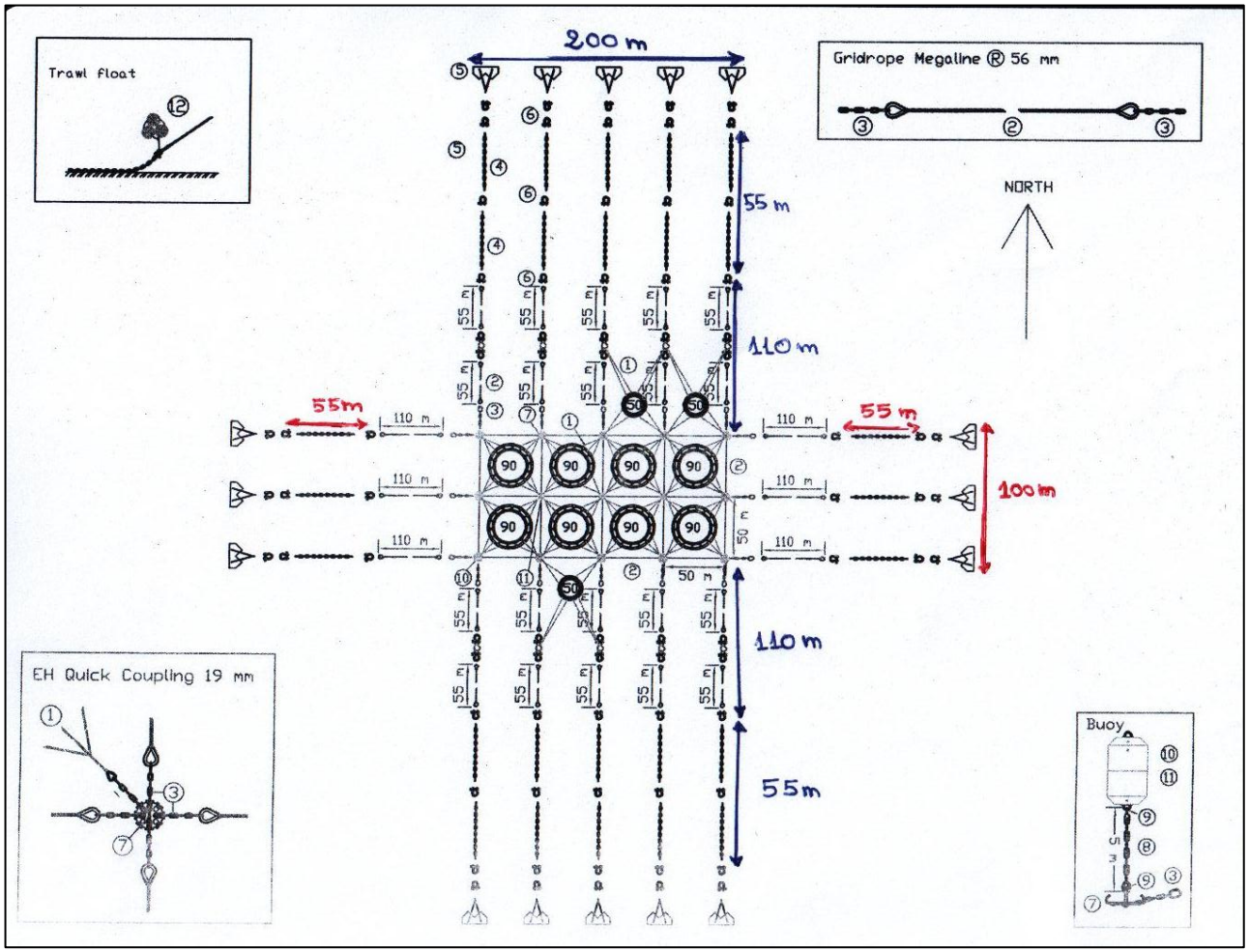
Certificate from supplier or designer of mooring system

Any mooring system should be appropriate for the environmental conditions expected at the site and should be designed to accommodate all expected husbandry operations, including the use of such equipment as feeding barges and work boats where necessary. For example, salmon farms using well boats will need to have in place sufficient mooring systems for the well boats in addition to the cage facilities. Consequently, any cage aquaculture operation should take great care in designing and installing the correct specification of mooring system. In some respects the mooring system of a cage farm can be considered equivalent to a building's foundations, since the integrity of the mooring system will affect the security of the cages, nets and fish stocks held in those cages.

The mooring system of a cage aquaculture operation should be designed by a company or consultant with demonstrable experience in this sector. In most cases the supplier of the cages or the mooring materials chosen for the fish farm will provide a full mooring specification based on an analysis of the expected environmental conditions at the site and the equipment to be used. A mooring system designed by a cage manufacturer or a reputable supplier of mooring equipment, and certified by that company as being appropriate for the conditions expected at the site, will reduce the risk of mooring system failure caused by its unsuitability for any particular location or use.

Mooring system analysis

For pre-existing farms without a clear and approved mooring design, an analysis can be carried out of the existing facility leading to an assessment of the suitability of the mooring system for the expected conditions at the site. A number of companies offer mooring



analyses of varying complexity and cost, and insurance risk surveyors will often carry out an analysis as part of a risk survey. However, the accuracy of this analysis is only as good as the data provided by the cage farm client, and so great care should be taken in providing the most accurate data possible for this analysis.

The simplest and most commonly employed analysis is known as a quasi-static analysis. This is a mathematical model of the forces exerted on the cage facility through wind and current action. To make this calculation, details of the size, orientation and geometry of the cages and nets are required together with an accurate estimate of maximum expected wind speed and current velocity at the site. This data is then input to arrive at an estimated total loading force to which the cage facility can be expected to be subjected to during the worst expected wind and current conditions. To this total actual load force a safety factor is added, varying according to the type of mooring component, to arrive at a specification of mooring component considered appropriate for that particular cage facility.

More complex dynamic analyses may also be carried out, which take into account the dynamic content of the various forces exerting on the cage facility, particularly wave action. Such analyses are often more expensive but might be considered for more extreme cage site environments exposed to significant wave action.

Any analysis will involve a questionnaire being provided to the client, asking for details of the number, size, shape and construction material of the cages in use, the dimensions and mesh size of the nets to be used, details of the net weighting system employed and details of any other equipment which might be connected to the mooring system, such as work boats, feeding systems, rafts, etc. This data is normally relatively easy to obtain and submit. The environmental data required for the analysis is usually more difficult to obtain but is critical to the accuracy of the analysis. Where possible, measured wind and current data for the site should be used to arrive at a safe maximum velocity for the analysis, typically those wind and current speeds which might be expected once in every 50 years. Many cage operations require such an analysis to be carried out as part of their original permitting requirements. Where such primary data is not available, maximum wind and current speeds should be obtained from meteorological stations in the area or other sources available in the public domain.

Obtaining maximum current velocity data may be problematic, since actual long-term current measurements at particular cages sites are often lacking. Where significant current action is present, the accurate estimation of maximum current speed is critical to the mooring design since current forces are proportional to the square of their velocity and so a slight over-estimate of current velocity will result in a significant over-estimate of mooring component strength requirements. Visual estimates of current speed are notoriously unreliable. Consequently, it is recommended that actual current measurements be taken at all cage sites known to be subject to significant current action. Measurements should be taken over a period of at least 15 days, to include a neap tide and spring tide. Since the strongest tidal currents of the year will occur during the equinoxes (20-21 March and 22-23 September of each year) an adjustment should be made to estimate the maximum tidal current from the measured readings. Weather conditions, in particular wind speed and direction, should also be recorded so that the wind-driven aspect of the total current measured can be estimated.
Although direct current measurements may be expensive and time-consuming to obtain, the additional cost of unnecessarily large mooring components in the event of an over-estimate of current speed, or the cost of a stock loss from mooring component failure in the event of an under-estimate of current speed, are certain to be greater.

Once the tidal component of the current velocity has been arrived at, a component for wind-driven surface currents should be added. This should be calculated as 2% of the sustained maximum wind speeds expected at the site (for example, a force 8 storm can be expected to produce a surface wind-driven current speed of 0.68-0.8 knots). It must be noted that some mooring analysis software will automatically calculate this wind-driven component from the maximum wind speed data provided.

Workboats

An allowance must be made for the tying of large workboats onto cages or mooring lines during routine husbandry procedures. A large workboat tied to a cage side-on to a strong wind and current can exert significant additional drag forces on a mooring system. Where large workboats are routinely employed, they should either be provided with separate dedicated moorings or, if they do need to be tied to the mooring system or cages for any reason, the load forces of the boat should be incorporated into the load calculations for the mooring system.

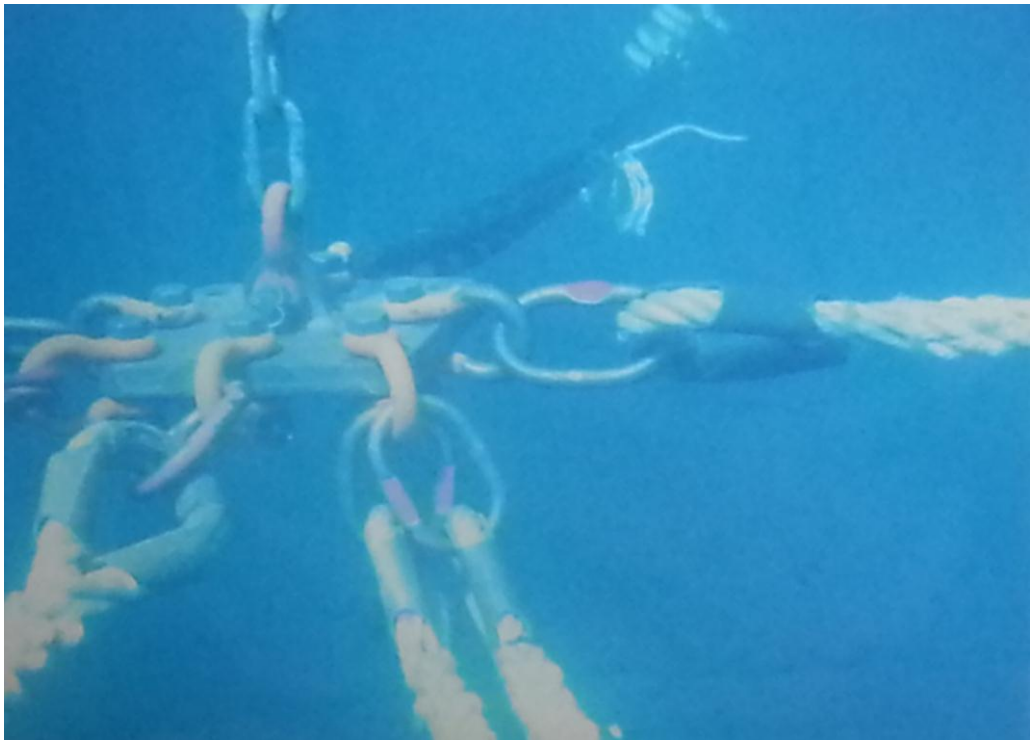
Mooring components

All components of a mooring system should be accompanied by a certificate from the manufacturer detailing the minimum working load or minimum breaking load (MBL) of that component. All components should be resistant to corrosion and appropriate for use in seawater.

Mooring maintenance and inspection

A well designed and thorough mooring inspection and maintenance programme is essential to maintain the mooring system in an optimum state of repair. Since the marine environment is highly dynamic and corrosive, all mooring system components are subject to constant wear and tear and require regular inspection to ensure that each component is maintained above its minimum strength requirements for the mooring system in question. An effective inspection and maintenance programme will also be able to forecast the expected deterioration of each component over time, and thus minimise the risk of unexpected component failure between inspections.

Each cage installation will be subject to different requirements for inspection and maintenance procedures due to the wide range of cage and mooring system designs in use and the different environments in which each cage installation is situated. Consequently, each cage facility must design its own inspection and maintenance programme based on the equipment in use and the environmental conditions experienced. However, a number of guidelines can be offered to assist in the development of effective inspection and maintenance procedures.



Documentation of inspection & maintenance procedures

The lack of adequate documentation of mooring inspection, maintenance and repair procedures is a very common problem in the aquaculture industry. Thorough documentation of procedures, inspections, maintenance work carried out and recommendations for further action are essential to an effective inspection and maintenance programme. Efficient documentation helps in the assessment of wear and tear on various components, allowing a forecast to be made of replacement frequency. It also aids in the employment of clearly-defined parameters needed to identify when any particular component is in need of repair or replacement. Most importantly, written records allow maintenance and inspection procedures to be reviewed and inspected by third parties, and allows teams of divers and technical personnel to work more efficiently during inspections. It also allows the existing state of a mooring system to be quickly assessed and provides written records which might help deduce the cause of any future mooring system failure.

The mooring system inspection and maintenance requirements will vary between cage facilities, and will depend on a number of variables, such as the cage types used, mooring system components employed, environmental conditions expected at the site, etc.

Consequently, a risk assessment should be carried out at of each individual mooring system. The risk assessment should include a full appraisal of each element or component of the mooring system, identifying those components thought most likely to fail and the consequences arising from the failure of that particular component. This risk assessment will then establish an inspection and maintenance programme with a frequency based on the risk associated with each component, expected wear and tear and the known weather conditions at the cage site. Where necessary, professional assistance should be sought for the completion of this risk assessment.

Mooring system inspection and maintenance documentation should include a full list of all mooring system components in use, and for each component a specified replacement requirement should be established. For each component a frequency of inspection should then be decided, based on the results of the risk assessment, expected life of that component, experience of actual wear and tear at the cage site and the weather conditions expected. The inspection procedure should involve a visual inspection of each component.

The following information should be recorded for each mooring component at each inspection:

- Exact position within the mooring system
- Month/year of installation
- Frequency of inspection
- Results of visual inspection, including any measurements taken
- Actions taken for any given component
- Recommendations for future action to be taken
- Name and signature of inspector

As a general rule a full inspection of the mooring system should be carried out at least once every 6 months. This would normally involve an inspection both before and after any seasonal period of bad weather. In addition, inspections should be carried out before any period of significant bad weather (if sufficient notice is available) and immediately after any period of significant bad weather. However, some components will require more regular inspections (such as cage bridles, cushion float shackles, cushion floats, etc) whilst others less frequent inspections (anchors, ground chain, etc). The actual frequency for inspection will depend on the risk assessment for any particular site. Also the degree of wear or damage triggering a requirement to replace that component will depend on the actual component in use, but as a rule of thumb any reduction in component thickness or diameter to 80% of the original thickness or diameter will require the replacement of that component.

In addition, a daily surface inspection should be carried out, noting the condition and presence or absence of cage bridles, the alignment of cages within the mooring system and the alignment of cushion floats. Any misalignment of cages or cushion floats can provide immediate warning of any dragging of anchors or failure of mooring lines, grid lines or cage bridles.

In addition to the routine inspection programme, a maintenance programme should also be established to include such tasks as the tightening of shackles, the tightening of bolts, lubrication, the replacement of shackle pin securing wires, tightening of mooring lines and

grid lines, and the adjusting of cage bridles. The type and frequency of maintenance required will depend on the results of the risk assessment and manufacturers recommendations for each particular component in use.

Spare parts

A full stock of spare parts should be maintained at the farm location, subject to the results of the risk assessment, to allow the rapid and effective repair of any foreseeable failure of the mooring system.

Summary of recommended requirements

1) A certificate from a reputable manufacturer or supplier of cages or mooring system components stating that the mooring system in place has been designed to withstand the expected conditions at the site, or
2) A certificate demonstrating that an accepted quasi-static or dynamic mooring analysis has been carried out on the cage facility in question, and that the strength of all mooring components exceeds the minimum load forces calculated, taking into account the various safety factors applied.
3) In addition to other meteorological data, actual current measurements are recommended for cage sites subject to significant current action. The measurements should be made over a minimum period of 15 days to include a spring and neap tide.
4) A risk assessment should be carried out for each individual mooring system in place, from which a dedicated inspection and maintenance programme can be designed.
5) Full written records should be kept of all mooring system inspection and maintenance procedures, work carried out and recommendations for future action. These records should be kept in a secure location and made available for subsequent inspection.

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