MANAGING RISK IN A CHANGING ENVIRONMENT

INSTALLING & MAINTAINING NETS IN AQUACULTURE

A Best Practice Guide

PARTNERING FOR PROGRESS

In 2009, RSA and WWF entered into a global partnership to strengthen the understanding of the links between insurance and environmental risk. Through joint research, emerging risk analysis and product development the two organisations are encouraging action among business, customers and governments.

Aquaculture is an important area for the partnership particularly in light of the rapid expansion of this industry around the world. These guides are aimed primarily at small to middle sized farms, particularly those being set up by people new to the industry. They might also be a useful reference guide for students, getting them to start thinking about best business practices, and also for insurance brokers and underwriters by highlighting the risks involved in aquaculture.

CONTENTS

INTRODUCTION

Aquaculture is a key focus area for the partnership between WWF and RSA, and understanding the issues and risks involved and mitigating their impacts is important.

RSA is one of the world's leading marine insurers and provides cover to aquaculture customers around the world. Reducing risk to customers is vital for business and the environment. These Best Practice Guides are intended to help the aquaculture industry develop better risk management. They complement the Aquaculture Stewardship Council guidelines which allow for certification to best practice standards of management internationally for a variety of fish species.

WWF has been instrumental in the development of certification standards for aquaculture that reduce or eliminate key environmental and social impacts. The standards will be managed by the Aquaculture Stewardship Council (ASC) and have been developed through a transparent multi-stakeholder roundtable process involving over 2000 people from all over the world in a process which has taken around seven years.

WHY BEST PRACTICE FOR NETS IN AQUACULTURE?

Net design and installation are key to the success of net pen aquaculture and the reduction in numbers of escaped fish. Nets are fundamental to keeping fish stock accessible to farmers for feeding and monitoring. They also offer protection against attack from aquatic predators and help to maintain optimal environmental conditions while keeping fish contained and preventing their escape.

Nets, despite playing a critical role in net pen farms, are often the weakest components of a net pen system. A number of factors usually combine to produce a containment breach or net failure resulting in escaped fish. As risks tend to be interconnected, a 'holistic' approach to examining risk must be taken. Risk factors are often site specific and peculiar to site conditions, system design and system operation however there are common factors to consider and manage risk.

Net failure can lead to what is called "loss of containment", the term to define the escape of fish from the enclosure to the environment. As well as representing a direct financial loss to the farmer, escaped fish present a risk to the genetic integrity of local wild fish populations. In addition, any farmer wishing to achieve certification by the Aquaculture Stewardship Council (ASC) will have to reduce escapes to a very low level.

It is in all parties' interests that farmers take steps to properly maintain net function and avoid escapes. This will increase profits in the long term due to improved growth and fish security. Staff training, precise reporting, more effective equipment and better working practices will all help to reduce the likelihood of net failure.

To optimise net function and security, consideration must be given to a number of factors including:

- net pen and mooring specifications,
- net design,
- equipment installation,
- maintenance,
- operational issues,
- fish transfer operations,
- predator protection,
- and vandalism.

"A recent study in Scotland showed that over 50% of escape incidents were due to holes in nets caused by predators, chafing and snagging, inappropriate siting and mooring failures due to the use of moorings inappropriate for the location."

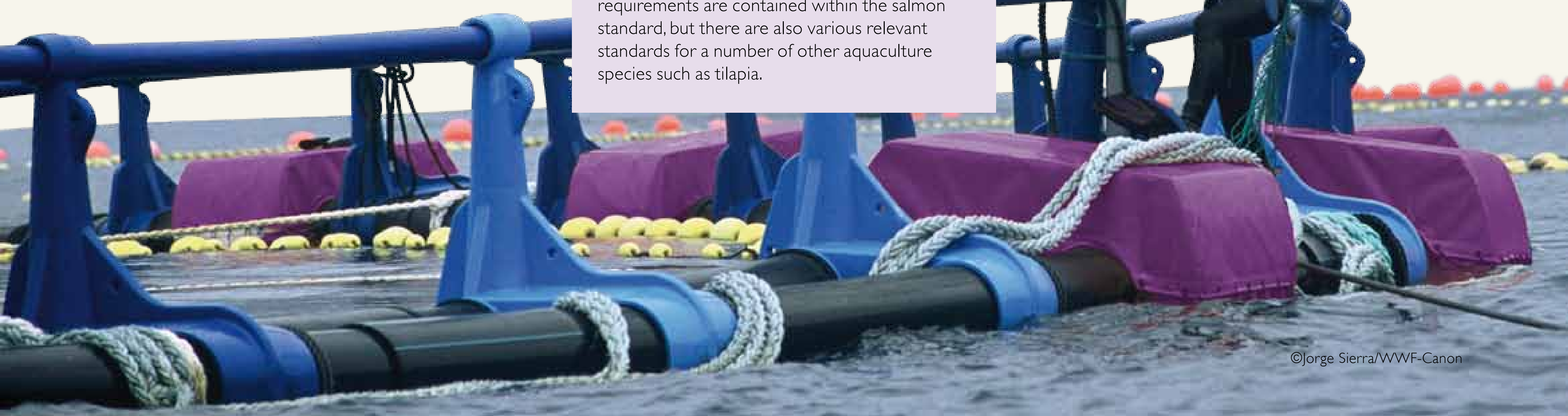
Fisher Farmer Magazine– Containment Special, May 2011

Understanding net pen systems

A 'net pen system' is comprised of components designed to absorb the energy from the waves, currents and winds affecting the site and maintain the net pen and stock in position. These components typically comprise anchors, floating net pen collars and mooring lines. The nets that hang from the net pen collars and form the stock enclosure are not designed to be a rigid or load bearing component of the mooring system. Understanding the interaction between the flexible containment net, the structure of the mooring system and net pen collars is key to optimising system design and reducing net and net pen failures. This principle is far more critical at exposed locations, where forces on the equipment tend to be more extreme, posing real challenges for offshore farmers.

THE AQUACULTURE STEWARDSHIP COUNCIL (ASC) ENVIRONMENTAL AND SOCIAL STANDARDS FOR AQUACULTURE

The ASC manages a global certification scheme for aquaculture with a number of environmental and social standards for the certification of fish and shellfish farms. Within the various species specific standards there are a number of requirements relating to the minimisation of escapes from net pen farms and the reduction of their environmental impacts. Most of these requirements are contained within the salmon standard, but there are also various relevant standards for a number of other aquaculture species such as tilapia.



INSTALLATION

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Moorings

Failure of a mooring system is a significant cause of escapes. Moorings are generally set up in a grid pattern where a number of net pens are attached to a set of moorings rather than each net pen having an individual system. A degree of redundancy should be applied to the design so that no single component failure can cause the loss of the whole system. Moorings can be attached by anchors or directly fixed to solid rock with rock pins.

The mooring system should be designed by a suitably experienced and qualified person who will take into account the conditions at the individual site and discuss previous weather events with local meteorologists and engineers to assess the likelihood of future events. A minimum ratio of 3:1 mooring length to water depth is typically considered desirable to absorb shock loadings on the net pens through the action of the moorings.

Where the mooring system and net pen components are inappropriately designed for the unique conditions on site there can be a transmission of forces and loads to the nets. An inspection should be carried out after installation, preferably by a qualified third party, to ensure moorings are laid out according to specifications. Any changes to the layout, such as adding more net pens, should be made in consultation with a qualified and experienced person, preferably the original design engineer.

Nets and materials

Net material can vary widely, from commonly used, affordable High Density Polyethylene (HDPE) materials, to more modern fibres such as Dyneema.

Rigid netting with extruded plastics and metals and nets of a chain linked or twisted design are now being used for ultimate predator control.

Each material has its own advantages and disadvantages. The choice of material will depend on environmental exposures at site, net pen designs, the species being farmed, ease of use and financial constraints.

The construction material of the net defines its density, breaking loads, diameter of the threads, size limitations of the net and ultimately the behaviour of the net within the net pen system. This influences the net's performance in adverse weather conditions, resistance to predator attacks and fish escapes, and will also impact on net weathering and biofouling. It is crucial to consider the different materials used in combination within the net containment system as each material will have different static and dynamic characteristics called resistance coefficients.

Knotted nets generally require more material to manufacture, making them heavier and more expensive. Knotted nets are less resistant to biting from predators, with each knot representing a potential weak point.

To overcome the above, knotless nets are now common, with designs made from Nylon, Polyethylene or Polyester, and the use of Dyneema also growing. A farmer needs to be cautious with ropes of different elasticity. Snap forces can be produced if used in an inappropriate combination. Always check with an expert.

Dyneema netting is used in combination with nylon ropes. The nylon rope is more elastic than Dyneema, and can stretch and lengthen. Dyneema does not stretch, and therefore in some cases nylon ropes have worked themselves loose following storm events, leaving the forces to be absorbed by the Dyneema netting. It is, therefore, important to check the condition of nylon ropes regularly and tighten where appropriate when used in combination with other material types.

Net testing

All nets purchased should have been tested by the supplier and if possible independently verified by a specialist third party prior to installation. Certificates should be retained for reference and in the event of a net failure or an insurance claim. (See maintenance section for further information on testing.)

Net tagging

Each individual net should be tagged to enable identification during inspection, maintenance and incident reporting. Every net should be tagged prior to installation.

Net shape and weighting

The shape of the net and maintenance of it in the water has a direct bearing on the volume of water within it. Maintaining a sufficient volume and flow of water for the biomass held will optimise animal welfare and the conditions for growth of the stock.

The material used in the net will largely determine its shape and size. The physical characteristics of the site (currents, water depth, and wave action) will also influence net shape and size. It is generally recommended that the net depth is between 0.8 and 1.25 times its diameter to better resist deformation in strong currents.

Ideally, nets should be slightly denser than water to enable easy handling by farm operators.

Weights must be hung correctly to maintain the correct shape, but without damaging the net. A properly weighted net maintains the culture volume for fish being raised and provides less opportunity for predators to damage the net (taut netting provides less purchase for bite damage). A loose billowing net can increase the risk of coming into contact with other structures such as boat propellers which can cause abrasions or tears.

Fish may also be at greater risk of ulcerative diseases caused by increased contact with moving and billowing nets.

Shadowing

Shadowing effects occur where a net pen or row of net pens shield neighbouring net pens from new water inflow.

A row of net pens on the trailing edge of a net pen group can dramatically reduce the water flow to adjacent net pens - current speed may decrease by 40% after passing through the first row of net pens and 65% when passing through the second.

When considering the biological demands of the fish in the net pens, and the addition of biofouling on nets it can be estimated that a third row of net pens would only receive between 10% and 20% of the required water flow.

Predator control

In locations that allow it (i.e. where currents are not too strong, and net pen equipment can support them, etc.) predator nets can be deployed, either partially or fully enclosing a net pen or group of net pens. This tends to be a wider gauge net held taut around the containment net, excluding predators from reaching the containment net within. However, there is a real danger of accidental trapping of diving birds and small seals using this type of net so great care and very regular monitoring should be carried out if this type of net is used. They should not be deployed in areas where wild animals are likely to become trapped.

Drag forces

Nets in the water exhibit a solidity density which can then be used to calculate the drag forces exerted by the water passing through the net.

The drag force exerted by a net is proportional to the water current it is exposed to, with the drag force calculated by the solidity factor of the net, multiplied by the current velocity squared; or in other words if the force exerted by a one knot current is 1 tonne per m^2, the force of a two knot current is 4 tonnes per m^2, and a three knot current 9 tonnes per m^2, and so on.

Biofouling can increase the solidity factor of a net by a factor of three, so it is easy to see that the degree of fouling on a net can have a huge impact on the forces at play in a net pen system and can significantly increase the risk of both net and mooring failure.

Information on antifouling measures can be found in the maintenance section on page 15.

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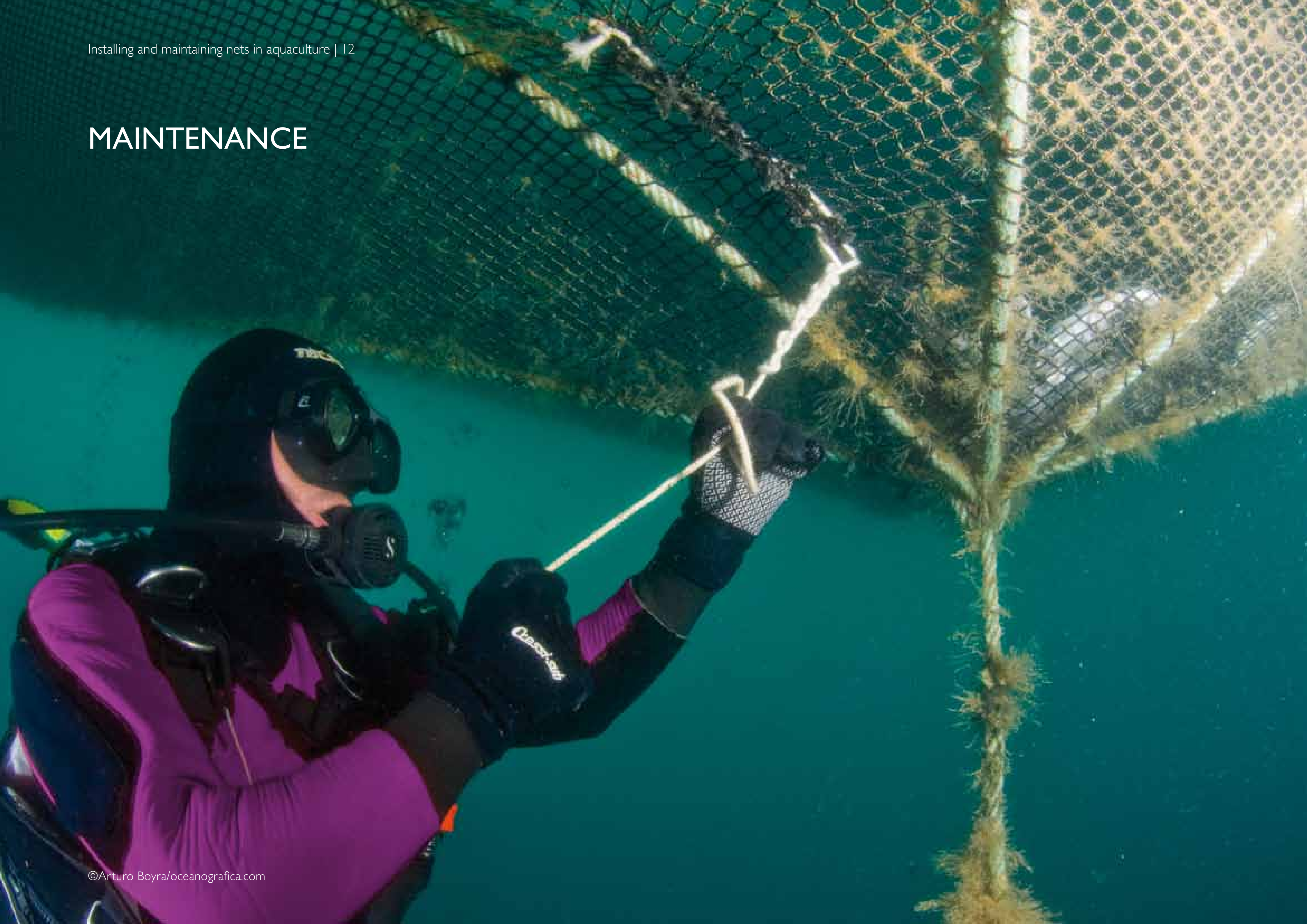
MAINTENANCE



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Net testing

As well as confirming the strength of the netting and net construction when new, it is crucial to monitor the performance over time.

Nets are exposed to long periods immersed in water. They are subject to constant movement through wave action and currents, abrasion risks from equipment and boats, UV degradation, biofouling, predator attacks and in some cases biting or nibbling by stock held within them.

Mechanical testing is the only real way to confidently assess the performance of a net. A number of net testing machines are commercially available, with some more basic than others, however testing should ideally include the following:

- Elastic limit;
- Breaking load (this will be the main factor determining the life span of the net);
- Lengthening;
- Resistance to cuts (especially important in bivalve aquaculture on longlines, or where bivalve operations are situated alongside net pen systems, e.g. integrated multitrophic aquaculture for example);
- Resistance to abrasion; and
- Tear continuity.

The following are current standards for aquaculture and fishing nets and should be used as reference when undertaking net testing, either by the farm or by a certified third party:

- ISO: 1197 – Fishing nets – Nettings – Basic terms and definitions.
- ISO: 1806: Fishing nets – Determination of mesh breaking force of netting.
- ISO: 1805: Fishing nets – Determination of breaking force and knot breaking force of netting yarns.
- ISO: 1530: Fishing nets – Description and designation of knotted netting.
- ISO: 3790 Fishing nets – Determination of elongation of netting yarns.
- NS - 9415/NYTEK – Technical Requirements for Fish Farming Installations – Norwegian Standard.
- Scottish Technical Standard for Containment at Marine and Freshwater Finfish Farms (in development).

"As well as confirming the strength of the netting and net construction when new, it is crucial to monitor the performance over time."

Control of fouling

The control of biofouling is critical for net based aquaculture production. Increased growth of organisms on the nets greatly increases drag in the currents (increasing the loads and stresses on the mooring components) and increasing the likelihood of breakage and subsequent escapes of fish. Fouling reduces the amount of clean, oxygen rich water reaching the enclosure. This can markedly affect fish growth, and can be a critical factor during low dissolved oxygen events such as slack tides, algal blooms and warm water.

The organisms themselves that make up the biofouling may also act as vectors for a number of diseases found in aquaculture, most notably parasites. Biofouling can also break down the net material through natural processes.

Net cleaning

The only current non-chemical alternative to antifouling is the manual cleaning of nets (onshore net cleaning machines using saline water baths or chlorinated water) or pressure water cleaning technologies used in situ. Pressure washing must be done with care as some pressure washers are extremely high powered and can damage net structure if inappropriate for the task. Nets treated with copper based anti-fouling products must not be washed at sea as this can lead to copper contamination of the water and seabed.

Mechanical removal of biofouling, although a heavy time-consuming task, is the only way to improve water quality within the enclosures without adding potentially harmful chemicals to the environment.

Other techniques include air drying the net (common in square metal net pen systems, where the net is pulled up and stretched across the net pen handrails, with the sun and UV drying out and breaking down the accumulated growth), and net cleaning 'robots'.

Net cleaning at site also has the potential to increase the nutrient levels in the benthos directly under the net pen system, and it is for this reason that net cleaning is recommended onshore away from the net pen site. Onshore net cleaning areas should also have an effective water treatment facility to prevent contamination of water from the effluent.

Predators

Predators such as minks, otters, seals and sea lions as well as large predatory fish such as the Mediterranean dentex and sharks will usually bite nets when trying to gain entry into a net pen enclosure. Interactions between net pen systems and predators can be reduced by removing dead or dying fish as soon as practically possible. Seal blinds can be used to prevent damage to dead stock at the bottom of the net pens; however this should not be a substitute for regular removal. It is important to ensure that the net weight system keeps the nets as taut as possible to reduce damage from predators. Some farms use predator nets which are fitted outside the net pen and separated to prevent direct contact between predator and the net pen net. Many predator attacks, particularly from seals, occur on the base of the net and false bottoms are sometimes used to prevent damage to the base of the fish net pen and subsequent escape of fish.

Snagging, chafing or tearing

Damage can occur through the interaction of the net with other components of the net pen system, such as shackles, mooring lines, bolts, and weights. It can be reduced by keeping the nets taut. Tearing is also caused by improper handling of the nets during removal and deployment.

Physical measures to ensure the separation of boats from net pens should be put in place where possible.

CURRENT ANTIFOULING SOLUTIONS AND NEW DEVELOPMENTS

ANTIFOULING COATINGS

The most common form of antifouling treatments are copper based, with the nets dipped before drying and installing on site. However, there are some environmental issues with copper based antifouling which should be taken into consideration such as those described above. It is important to ensure that any antifoulants used are approved according to local legislation in the European Union, United States, or Australia in order to comply with the ASC standards for salmon. If copper antifoulants are used, the sediments should be tested annually for copper to ensure that the level is consistent with background levels and does not exceed 34 mg Cu/ kg dry sediment weight.

BIOLOGICAL CONTROL USING ORGANISMS THAT FEED ON THE BIOFOULING

This solution employs the use of marine organisms, such as crabs and starfish, to control the growth of biofouling on the nets. Still under research, it appears to be some way off commercial viability.

NON-BIOCIDE ANTIFOULING COATINGS, USING NANOTECHNOLOGY

Still under research, new coatings or net materials are being trialled to reduce the ability of organisms to adhere to net surfaces. There have been some promising results to date, but results may come at increased cost to the farmer, and the dynamics of the nets themselves will undoubtedly change with different materials used.

Reference: The Salmon Aquaculture Dialogue provides requirements to ensure that chemical inputs to the environment are controlled, especially regarding the treatment and cleaning of copper nets, anti-fouling-coated nets and accumulations of metals on the benthos as a by-product of using copper nets and copper-based anti-foulants. These standards can be found under Criterion 4.7 of the Salmon Aquaculture Dialogue. Updates and developments can be found on the WWF website, see further reading at the back of this guide.

NET MAINTENANCE RECOMMENDATIONS

Given the significant impact of net failures on farming operations, and the strict ASC requirements for reducing escapes, a thorough and systematic approach to net maintenance must be in place.

Monitoring of net performance is essential and regular inspections of nets both in the water and onshore are required to minimise losses.

Visually inspect nets at least once a month

Visual inspections are crucial in confirming the integrity of the nets, and ensuring that the nets are properly functioning. The upper sections of the nets are easily observed, however depths greater than two metres generally require either remote survey using cameras and Remotely Operated Vehicles (ROV) or divers.

Inspections must be as frequent as possible (at least once a month) and should also be carried out following extreme weather events or environmental conditions that can affect nets. Inspections should be given a high priority by management and carried out by staff dedicated to the task and with sufficient time to do so, and be properly supervised and recorded.

Visually examine lines, knots, and system components on a regular basis

Visual inspection of the installation accessible to farm operatives must be performed on a regular basis (preferably daily), with emphasis on the mooring components and those coming into contact with nets. Corrective action must be taken as soon as possible, with staff trained to recognise abnormal equipment configurations that could lead to problems. Written reports must be made at each inspection including any corrective action taken or timelines for correction and completion dates.

In addition to routine net checking, a thorough visual examination of the whole system (both surface and below water) should be undertaken before and after certain operations that could cause net damage such as net installation, net changing and net lifting, as well as after extreme weather events.

Ensure nets are cleaned regularly

Cleaning requirements are heavily dependent on site location, season and type of nets used. Frequency of cleaning depends on scale of fouling and this will vary with temperature and input levels, time of year and the location. It is recommended, and in some cases a requirement, to move nets off site before cleaning.

When cleaning nets, the following should be taken into consideration:

- High pressure washers should be avoided whenever possible to avoid damaging nets;
- Hauling the nets from the water using a single vertical rope without supporting span ropes can result in damage to the net;
- Net tears should always be expected when removing and re-deploying the nets. A diver or ROV inspection should be undertaken prior to re-stocking;
- Extra care should be taken when lifting heavily fouled nets. They should be stropped in appropriate places to spread the load evenly down span and vertical ropes otherwise severe point loads can occur on the netting itself causing failure; and
- Nets left ashore must be checked thoroughly before deployment as animals such as rats and mice may cause damage to the nets, and vehicles inadvertently driving over sections of them could damage net integrity.

Replace nets every three to four years

Even with modern net technology vastly improving the strength and durability of nets and materials, it is generally accepted that nets should be retired after three to four years of use.

Nets should also be changed as soon as the breaking strength falls below 65% of original net strength in the walls and bottom of the net, and below 60% at the point where the net is attached to the net pen collar.

Adjust bird nets

Bird nets require constant adjustments, with taut bird nets exerting undue stress on the handrails, and loose nets dragging in the water, reducing their effectiveness against birds. This can also present an entrapment risk for fish and birds.

MAINTENANCE TIPS:

- Ensure regular inspections for damage and fouling
- Inspect all nets after adverse or abnormal weather or sea conditions
- Check that the mooring components and knots are secure
- Check mooring lines and net lines do not show signs of wear and tear
- Repair small holes temporarily using coloured thread. Damaged netting can then be easily identified and properly repaired using thread with a higher breaking load when possible
- Patch large holes if detected; and
- Check the nets periodically, this should be done by the net supplier or manufacturer, or by an independent surveyor and inspection should include mechanical testing where possible

DAILY NET LOG BOOK

Verifiable records should be kept of all escapes. The ASC will employ independent global certification bodies to carry out audits. Therefore to obtain ASC certification, farmers will need to present both their escapes records and equipment inspection records.

A daily log book for best practice should include:

- Number of days the net has been operational;
- Details of net history (repairs, inspections, maintenance), including dates and related SOPs (Standard Operating Procedures);
- Results of each task;
- Net failures should be documented, with the following information recorded:
  - Date of discovery and name of person reporting the net failure;
  - Description of the failure;
  - Description of the section of the failed net (e.g. net panel, rising rope, net floor) and possible cause of the failure;
  - Repairs undertaken and date;
  - Action taken to avoid the same or similar losses happening again.

SAFE DISPOSAL OF NETS

All non-biological waste produced by a farm should be recycled, reused or disposed of properly and must not affect neighbouring communities. ASC compliance will require the presence and evidence of a functioning policy for the proper and responsible treatment and disposal of non-biological waste including net pens.

EDUCATION AND TRAINING

Human error is a significant factor in fish escapes. Training should be a key requirement in any net pen farming operation. Training should start during the induction of new staff with the use of models and graphical representations of net systems or preferably with real systems at an unstocked site. The training should be ongoing, and revisited regularly to ensure that best practices are passed on to all employees involved in net pen management and operations. Training should also be provided for operators of boats, forklifts and cranes that might come into contact with nets.

Where mistakes or failures occur, these should be recorded and practices altered to avoid potential loss situations arising. New equipment and net materials should ideally be tested thoroughly at site before stock is introduced.

FURTHER READING

Jensen Ø et al., (2010). Escapes of fish from Norwegian sea-cage aquaculture: causes, consequences and methods to prevent escape. Aquaculture Environment Interactions vol 1. 71-83.

Taylor, M., Kelly, R. (2010) Assessment of Protocols and Development of Best Practice Contingency Guidance to Improve Stock Containment at Cage and Land-based Sites Volume 1: Report. pp 74. ISBN: 978-1-907266-30-0 http://www.sarf.org.uk/reports/SARF054

Taylor, M., Kelly, R. (2010) Assessment of Protocols and Development of Best Practice Contingency Guidance to Improve Stock Containment at Cage and Land-based Sites Volume 2: Supporting Information. pp 177. ISBN: 978-1-907266-31-7 http://www.sarf.org.uk/reports/SARF054

Eva B. Thorstad, Ian A. Fleming, Philip McGinnity, Doris Soto, Vidar Wennevik & Fred Whoriskey Incidence and impacts of escaped farmed Atlantic salmon Salmo salar in nature. Report from the Technical Working Group on Escapes of the Salmon Aquaculture Dialogue. January 2008. http://wwf.worldwildlife.org/site/PageNavigator/SalmonSOIForm

FOR MORE INFORMATION

Aquaculture Stewardship Council (ASC)
www.ascworldwide.org

www.preventescape.eu

http://www.worldwildlife.org/what/globalmarkets/aquacultureaquaculturedialogues.html

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WWF

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To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

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