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Marine finfish farms — Open net cage — Design and operation

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National foreword

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Contents

Page

Foreword

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 234, *Fisheries and aquaculture*.

Introduction

This International Standard is developed to ensure that a net cage marine finfish farms are adequately designed, constructed, and maintained to meet the anticipated rigours of the marine environment in which they will be deployed to prevent escapes (unintended impacts) during every day operations and unforeseen events. The standard is to be applied by the farm operators on a site-specific basis. Aquaculture producers are recommended to ensure that the combination of technologies that they have selected for a site meets environmental and other operational considerations for that site. Equipment manufacturers can use this International Standard, methodology, and terminology so that their customers (farm operators) can have the opportunity to meet the requirements with this International Standard.

The physical rigours of the marine environment to which a net cage marine finfish farm can be subjected include tidal currents, wave action, storm surges, hurricanes, wind exposures, icing; equipment design (net cage structures, mooring systems, netting components, predator control, and site markers. Other factors influencing the integrity of a net cage marine finfish farm include qualifications of equipment manufacturers and suppliers, handling practices, inspection and maintenance, reporting and auditing, and stock loss and recovery planning.

Within marine aquaculture, an increasing degree of farming on high energy sites (strong tidal currents, wave action, storm surges, hurricanes, wind exposure, icing) is predicted. Further developments in equipment and technology for farming in cages on high energy sites can result in improved water quality and fish health. The use of high energy locations will necessitate improvements of cages, mooring systems, and feeding systems. It can also require larger boats for servicing, and calls for new techniques for installation and daily operations.

This international technical standard is intended to reduce technical and operational failures, consequently enhancing the sustainability of the industry. All precautions are recommended to be taken to prevent escapes (unintended impacts) from aquaculture installations as a result of improper specification of technical main components or improper operational use. This International Standard will offer one tool in a link of other guidelines needed for the aquaculture industry to be environmentally sustainable.

Marine finfish farms — Open net cage — Design and operation

1 Scope

This International Standard presents a general method to be followed for the systematic analysis, design, and evaluation of net cage marine finfish farms. One common style of a net cage finfish farm is shown in Figure 1. A mooring system holds together a series of net cages which contain finfish. Water from the outside environment freely passes through the nets, providing the necessary environment for farming finfish. The methodology presented in this International Standard allows for determination of the adequacy of a given finfish farm's floating structure, nets, and mooring equipment for a given environment. The standard addresses specification of a design basis through evaluation of environmental conditions and acceptable risk, and specifies acceptable techniques for the design and analysis of finfish farms. This International Standard also provides guidelines for development of a handbook which documents procedures for correct maintenance and operation of the finfish farm.

The application of the standard is intended to reduce the risk of escape from marine finfish farms. This International Standard is designed to be used by the operator of a net cage marine finfish farm. It is intended that through application of this International Standard that increased human safety and system integrity levels can be achieved.

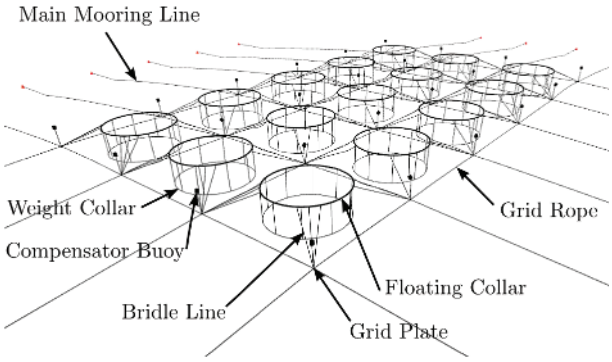

Figure 1 — Typical net cage marine finfish farm design

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1107, *Fishing nets — Netting — Basic terms and definitions*

ISO 19900, *Petroleum and natural gas industries — General requirements for offshore structures*

ISO 19901-1, *Petroleum and natural as industries — Specific requirements for offshore structures — Part 1: Metocean design and operating conditions*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
cage
floating collar with attached net cage for the purpose of containing finfish

3.2
floating collar
frame which provides buoyancy and attachment for one or more net cages

3.3
net cage
net construction attached to a floating collar for the purpose of containing fish

3.4
net pen
net construction that rests on the seabed and whose purpose is to contain fish

3.5
mooring system
system of lines (e.g. polyester rope, chain, wire rope) and bottom attachments for the purpose of keeping the floating components in a desired position

3.6
barge
floating work station on a marine finfish farm, separate or integrated, with technical equipment for performing certain functions connected to fish farming

Note 1 to entry: The barge can have functions as storage, feeding, electricity supply, crewing, and monitoring of the site and others.

3.7
marine finfish farm
containment system for the purposes of farming finfish

Note 1 to entry: A marine finfish farm typically consists of a mooring system, floating collars, anchoring system, net cages, and can include a barge.

3.8
net cage
containment system through which water freely flows through the net cage from the outside environment

Note 1 to entry: This is in contrast to closed containment systems, in which water from the outside environment does not pass freely through the structure.

3.9
predator net
barrier cage preventing predators from entering the net cage

Note 1 to entry: A predator net could be a birdnet, jumpnet or other types of nets used for protection against predators such as e.g. birds, sea lions, seals, and sharks.

3.10
operator
party responsible for the operation of a net cage marine finfish farm and may or may not be the owner or producer

3.11
supplier
organization that provides a product or a service to a customer

3.12
floats
buoys
component which is typically attached to a mooring system to provide buoyancy or mark boundaries

3.13
anchor
device that is used to connect the marine finfish farm mooring system to the sea bed to keep the fish farm in place

3.14
compensator buoy
device used to provide flotation and add compliance to a mooring system

Note 1 to entry: The compensatory buoy is intended to compensate for changes in water level and maintain tension in the mooring system in waves.

3.15
metocean data
meteorological and oceanographic data

3.16
limit state
limit state is a condition of a structure beyond which it no longer fulfils the relevant design criteria

3.17
global analysis
overall numerical analysis of the complete structure, such as a the complete marine finfish farm, to determine overall loads and response

3.18
stability log
document with information and specifications regarding the stability of a barge

3.19
tolerance limit
load capacity limit of a component

3.20
return period
average period between occurrences of an event or a particular value being exceeded

Note 1 to entry: For environmental events, this is typically measured in years.

3.21
floats
flotation devices that are used to give floating to a raft-cage system that arranged in the lower section of hall square cage

3.22
side walk
square structure, preferably galvanized steel, which also allows transit corridors, containing floats at the bottom that give buoyancy to raft-cage system to this place is attached the net cage

3.23
counterweighs
weights that serves to reduce the deformation of the net cage against prevailing currents in the area of culture

Note 1 to entry: Counterweighs are generally constructed of concrete.

4 Basic considerations and general requirements

4.1 General considerations

This International Standard is intended to provide guidelines for the design and operation of permeable net cage marine finfish farms similar in design to those shown in Figure 2 and Figure 3. The owner/operator of a marine finfish farm is responsible, through the use of a risk evaluation, for assessing the environmental conditions at a prospective site, selecting the appropriate equipment for use at the particular site, and for the safe operation of the finfish farm.

The main components should be designed according to ISO standards that are relevant for the component in question. Where ISO standards do not exist, appropriate international or regionally accepted standards should be applied to ensure a high level of system safety and quality assurance. For example, the design of a steel structure should use ISO 19902 or EN 1993.

Internationally accepted codes and standards that exist and which provide guidelines for the technical design and integrity of system components may be used. However, the user must ensure that the design philosophy intended in this International Standard is met and consistent operational and human safety levels are applied.

As shown in Figure 2 and Figure 3, a marine finfish farm typically consists of the following main components:

a) floating collars;

NOTE The floating collar is designed to hold nets in place, and gives the net cage flotation and structural shape. Floating collars are frequently constructed of HDPE plastic pipe or galvanized steel.

b) mooring system;

NOTE The mooring system is used to restrict the motion of the entire finfish farm, enabling it to keep stationary. For example, the mooring system shown in Figure 1 is composed of a mooring grid, bridle lines, and main mooring lines.

c) anchors;

NOTE Anchoring systems typically consist of concrete blocks (gravity anchor) or drag embedment or plate anchors (such as Danforth style anchors) which, when connected with the mooring system, keep the finfish farm in a fixed position.

d) net cage;

NOTE A net cage is typically made of rope and nylon netting and is used to contain finfish.

e) predator net;

NOTE A secondary netted system is often used to prevent predators such as sharks and sea lions from breaking into the net cage.

f) barge;

NOTE Both feed and accommodation barges are common at finfish farms in many regions. The barge is frequently used as a monitoring platform for the fish farm operations.

g) other components.

NOTE These could be floats, sidewalk and counterweights.

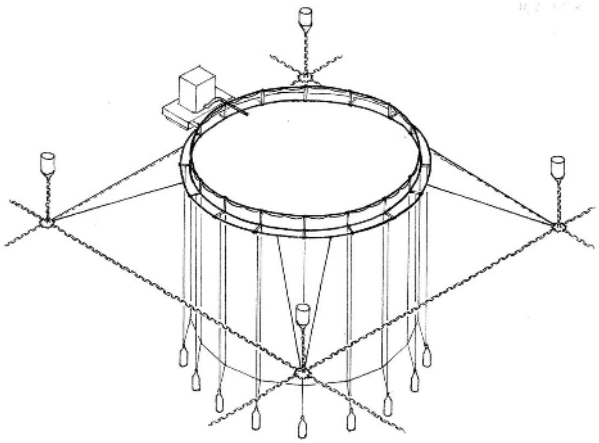

Figure 2 — Typical HDPE floating collar finfish farm configuration

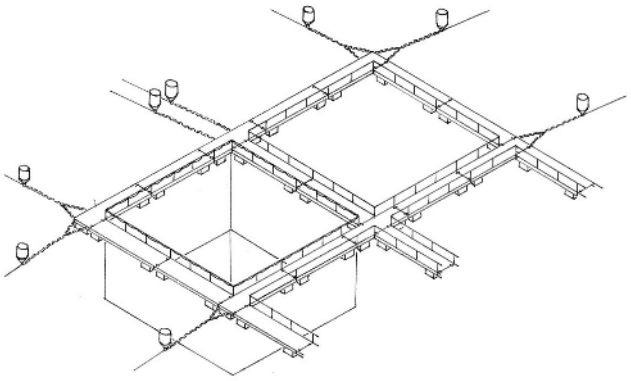

Figure 3 — Typical steel frame floating collar finfish farm configuration

4.2 Site survey requirements and environmental considerations

Fish farming sites range from very protected to the very exposed and, as such, containment structures need to be designed and constructed with particular attention paid to the site-specific rigours of the marine environment in the location where they will be deployed. For example, fetch, bottom type, and tidal currents will vary greatly between sites and can affect wave size, anchoring options, and mooring lines size, respectively.

The site shall be surveyed and described based on bathymetry, topography, and degree of exposure. This data (e.g. fetch, bathymetric map, site boundaries, bottom type, etc.) shall be used for the calculation of environmental conditions and assessment of the suitability of the equipment.

The site survey should be used to determine the feasibility of developing a finfish farm at a potential location.

The design and selection of components for a marine finfish farm will vary depending on the environmental conditions at the site. The impact of currents, wind, and waves on permeable net cages will be relevant to consider in all parts of the world. Additional loads must be considered in certain regions, such as snow and ice loads.

The owner or operator of the site shall assess, or have assessed, the environmental conditions at the site according to the guidelines presented in this International Standard. The assessment shall be completed by experienced and qualified personnel. Expertise and methodologies have been developed

for the effective evaluation of meteorological and oceanographic information for ocean industries such as the marine renewable energy and offshore petroleum and natural gas industries. General guidelines and background information on collection of meteorological and oceanographic information for the purposes of defining extreme environmental conditions for the design of ocean structures can be found in ISO 19900 and ISO 19901-1. Where possible, these existing best practices should be reasonably applied.

It is noted that even in areas such as the Gulf of Mexico and the North Sea where a great deal of reliable measurements have been collected for the purposes of designing ocean structures, this data are often insufficient for rigorous statistical determination of extreme environmental conditions at specific locations. Therefore, the determination of appropriate design parameters must be completed with sufficient care by experienced personnel. Lastly, many fish farms are located in inshore or near shore locations; not all standards for assessing environmental conditions for offshore locations will directly apply to near shore or inshore locations. Therefore, sufficient care should be exercised when using standards developed for offshore locations.

In general, meteorological and oceanographic measurements should be performed on empty sites (i.e. a site without an installation) if possible prior to development. Clause 6 provides guidelines establishing environmental design criteria for a finfish farm.

4.3 Degradation and lifetime considerations

The choice of components must be considered in relation to the lifetime considerations and the degree of inspection and maintenance of the different components.

4.4 Risk analysis requirements

A risk analysis, broken down into probability and consequence, shall be performed in connection with the design and operation of the finfish farm.

The risk analysis shall be based on accepted procedures, such as those laid down in already established applicable ISO standards (i.e. ISO 31000 and IEC 31010) or standards that are comparable to the ISO standards. The various stages shall be documented so that they can be re-examined.

A risk analysis shall be as complete as reasonably possible during the design phase.

4.5 Design of marine finfish farms

4.5.1 General

The marine finfish farm shall be designed with the objective to prevent fish escapes. The design shall be reviewed by personnel with sufficient expertise and experience. Documentation of each of the main components shall be such that the design can be evaluated according to this International Standard. Consideration shall be taken of extra loads one main component receives from the others, and it shall be established by calculations, research, or numerical modelling that each main component has the capacity to withstand these loads.

4.5.2 Limit state analysis

The finfish farm shall be designed according to the requirements and considerations presented in Clause 7. Clause 7 lays out a set of limit states for which different design situations must be assessed. The limit state analysis approach is similarly used for assessment of offshore structures and mooring systems.

Alternative internationally accepted codes and standards exist which provide guidelines for the design of floating structures and mooring systems that may be utilized in lieu of the limit state approach; however, the user must ensure that the design method objectives intended in this International Standard is met and a consistent safety level is applied. For example, API RP 2SK[20] for the design of station keeping systems (moorings) for offshore structures uses a safety factor approach that could be applied to the design of a finfish farm mooring system.

4.5.3 Functional requirements

In addition to meeting the containment objective of preventing fish escapes through the design states as in Clause 7, the marine finfish farm design shall also consider

a) safety of personnel,

b) protection of the environment, and

c) serviceability.

4.6 User handbook

A master user handbook containing information on the site design, the components critical for the integrity of the marine finfish farm and the day to day operations of the site including maintenance and inspection and also the site design, shall be created. This handbook contains as detailed as reasonably possible documentation on all of the main components of the farm, such as the nets, mooring system, and barges. A site maintenance plan shall be developed and outlined in the handbook. The user handbook shall also include a plan for removal, transport, and reinstallation of the cage system. The user handbook will be stored in a location so that site operators can access the handbook in the day-to-day operations of the site. The specific requirements of the user hand book are presented in Clause 5.

4.7 Assembly of main components

When assembling a finfish farm, the following must be considered:

a) three-dimensional geometry of the main components shall be such that they do not cause chafing on any of the other main components;

b) materials in and protective coating on parts which connect the various main components, shall be such that they do not cause one another extra corrosion due to galvanic conditions;

c) connecting points between main components shall cause as little wear on adjacent equipment as possible;

d) connecting points between two main components shall be such that connection and disconnection is simple, without compromising the strength and reliability of the connecting function itself;

e) the main components shall be designed so that they do not complicate or impede inspection, maintenance, repairs, cleaning, and replacements of other main components or parts of them;

f) the composition of main components shall be in accordance with environmental loads such as they appear in the site survey.

NOTE The installation of e.g. the mooring system is of particular importance.

4.8 Inspection of marine finfish farms after installation at the site

An inspection of the completed installation of the marine finfish farm at the site shall be performed. This inspection shall consist of the following at a minimum:

a) checks that the marine finfish farm installation and its main components are placed at the sites as planned, and that conditions reasonably conform to those on which all calculations are based;

b) checks that all anchors are placed in accordance with the specifications;

c) checks that all the parts are in accordance with the required parts as listed in the user handbook;

d) checks that all the main components are connected in accordance with technical specifications;

e) checks that the main components are undamaged after transport and assembly;

f) checks that the user handbook is available for further daily operation.

This inspection shall be documented.

Safe manoeuvring of boats around the finfish farm shall be assessed and documented.

The as-built configuration of the marine finfish farm shall be drawn on a site map that shows the placement of main components: floating collars, barges, moorings, and anchor locations.

In the event of deviation between the planned marine finfish farm and its operational set-up after it has been placed at the site, an assessment shall be made and documented of whether a revised or updated analysis as per Clause 7 is necessary or not.

5 Requirements for documentation and user handbook

5.1 General

A master user handbook containing information on the components critical for the integrity of the marine finfish farm, the day to day operations of the site, and the site design, shall be created. This handbook will contain documentation on all of the main components of the finfish farm. A site maintenance plan shall be developed and outlined in the handbook. The user handbook will be stored in a location that site operators can access the handbook during day-to-day operations of the site.

A user handbook may be compiled in either electronic or paper form (e.g. a tablet computer or binder). The handbook shall be organized clearly for use by all finfish farm site personnel.

During operation of the site, a site log shall be maintained that records day-to-day maintenance operations at the site, as further described in 5.2.

The following chapter outlines the specific requirements of this hand book and operations log.

5.2 Requirements regarding user handbook

5.2.1 Contents of user handbook

The contents of the user handbook shall reflect the basic risk evaluation which is the basis for the individual main components, and for the marine finfish farm installation and site as a whole. The handbook shall be formulated so that it contains as much traceability information as possible, both for parts and their supplier or manufacturer.

The language in a user handbook shall be simple, and difficult technical expressions shall be avoided. However, where they are used, they shall be defined. Theoretical descriptions and complicated explanations shall be avoided. Illustrations should be used where they shall contribute to simplifying the understanding of the construction and operating procedures.

The user handbook shall be revised at regular intervals or when significant changes, such as a new component, take place. It shall form the basis for traceability and a process for deviation handling.

The user handbook shall contain the following as a minimum:

a) general site information:

   1) map and coordinates of site;

   2) description of site use (e.g. intended species);

3) description of site environmental, meteorological, and oceanographic conditions;

b) site equipment information:

1) list of main components (e.g. floating collar, net cage, moorings, barge, and auxiliary equipment);

2) supplier/manufacturer provided documentation of main components;

3) lifetime of main components;

c) summary of global analysis:

1) site design criteria (wave, current, ice, and wind conditions);

d) site maintenance procedures;

e) site inspection program;

f) documented uninstallation procedure, transport, and reinstallation of cage.

5.2.2 Requirements regarding general site survey documentation

a) map siting the boundaries of the installation in the immediate geographical area shall be provided;

b) description of the site's intended use;

c) description of the environmental conditions which the main components shall tolerate, including wind, current, waves, temperature, and other relevant regional environment loads such as ice.

NOTE The environmental conditions report for the site may be included in the handbook to satisfy this requirement.

5.2.3 Requirements regarding documentation of main components

5.2.3.1 General

Documentation shall be compiled in the user handbook for the main components:

a) floating collars;

b) net cages;

c) mooring systems;

d) anchors;

e) barges;

f) auxillary equipment.

General arrangement drawings for the complete marine finfish farm that indicates connections between main components shall be included.

A parts list shall be provided which indicates part numbers and key identification information, such as serial numbers.

The following shall be provided for the main components in the user handbook:

a) name of supplier or manufacturer;

b) procedures for transport and handling of equipment;

c) summary of the environmental conditions in which the equipment is designed to operate;

d) statement of the analysis methods and standards to which a component was designed and constructed, and the person or organization which conducted the analysis;

e) certificates and declarations which confirm the compliance of parts with standards and other specifications;

f) certificates for certified parts which provide traceability.

5.2.3.2 Additional specific requirements for net cages

The following information shall be provided in the user hand book for net cages:

a) twine number, mesh length, mesh type, rope type, and size of the mesh in the form of a half-mesh in accordance with ISO 1107;

b) date of production;

c) description of all allowable attachments methods and systems to the floating collar;

d) documentation concerning knotting, splicing, sewing, binding, and impregnation;

e) species of fish for which the net cage is intended;

f) drawing of the net and its construction;

g) recommended weighting system and maximum allowable forces on any net connection point.

5.2.3.3 Specific requirements for floating collars

The following information shall be provided in the user hand book for floating collars:

a) maximum allowable mooring line forces on any connection points;

b) maximum allowable forces from net cage and weighting system on any connection points.

5.2.3.4 Specific requirements for permanent feed and supply barges

The following information shall be provided in the user handbook for barges:

a) maximum allowable mooring line forces on any connection points;

b) recommended mooring line layout and mooring components;

c) drawings (post construction) shall include system drawings for ballast, draining, cooling water, fuel oil, compressed air/plant air, hydraulics, air and sounding, fire and hosing, to the degree it is relevant for the barge concerned. System drawings for electrical installation, including low voltage, shall also be available.

d) the stability log shall be available with drawings of the barge's overall dimensions and with stability updated with the results of the heeling tests;

The stability log of each barge shall contain the following information:

— main dimensions and capacities of the barge;

— general arrangement;

— tank plan;

— watertight integrity plan;

— results of heeling tests, or results from heeling tests of a prototype with confirmation of accordance;

— instructions regarding loading;

— calculation of ice load;

— intact stability;

— damage stability;

— hydrostatics;

— cross curves.

5.2.3.5 Specific requirements for the mooring system

a) documentation of the mooring system shall give a description which is good enough to be able to assess/recalculate the moorings;

b) list of the required pre-tension in each line;

c) attachment method of each mooring line to the finfish farm structures;

d) specification of each mooring line, at a minimum an overview of building up in segments with bottom attachment/shore attachment, line type, grommets, shackles, and other extra equipment. The mooring line's diameter, minimum allowable breaking strength, buoy, deadweight with weight, volume and placing and material data such as elasticity and weight per unit of length shall be stated where relevant;

e) overview of the segments and equipment that make up a mooring line (e.g. chain, polyester rope, shackles, buoys) shall be given;

f) rating and classification of shackles shall be stated;

g) minimum allowable breaking strength in chains and ropes shall be stated;

h) description of each anchor or bottom attachment shall be available. At a minimum, this shall include a statement of the type of anchor (concrete weight, drag anchor, rock bolt, etc.) as well as mass and weight or expected holding power;

i) specification of each shore attachment shall be available. At a minimum, this shall include dimensions of the bolt, attachment method, corrosion protection, ground conditions, and other relevant data.

5.3 Requirements regarding site operations and maintenance log

5.3.1 General

During operation, a site log shall be kept, which at a minimum, shall include the following:

a) actions performed (type of inspection, maintenance, or repair), with a reference to plan and procedure;

b) results after action performed;

c) necessary follow-up as a conclusion after action performed;

d) date actions performed and follow up conducted;

e) person/institution performing the action;

f) verification of person/institution performing the action (e.g. signature).

5.3.2 Requirements regarding site and equipment maintenance plan

All maintenance shall be described in a detailed maintenance plan. The maintenance plan, at a minimum, shall contain an overview of what types of maintenance are required, at which times they shall be performed during the calendar year, and at which time intervals they shall be performed.

The main philosophy of the maintenance plan shall be that the identified qualified person responsible for the daily operation shall perform/oversee the necessary maintenance of the marine finfish farm with its main components.

The handbook shall give clear rules for how maintenance performed shall be entered into a log, or documented in another manner and the maintenance routines shall be so well described that the competent personnel shall be able to perform them without access to other information than that provided in the handbook. A description shall be given of what type of competence is required for personnel performing the various types of maintenance.

The maintenance plan shall be based on a risk analysis. This means that the plan shall be directed towards the elements/parts which will result in the most serious impacts if they should fail.

The maintenance plan shall be related to the parts list. All parts in the overview shall be identified with what type of maintenance they require and how often this shall take place.

5.3.3 Requirements regarding site inspection program

Inspection programs should be detailed, and at a minimum, shall include an overview of types of inspection required, times during the calendar year they shall be performed, and at what intervals they should be performed.

The main philosophy of the inspection program shall be that the person responsible for the daily operation shall also perform/oversee the necessary inspections. The handbook shall give clear rules for how an inspection that has been performed shall be entered into a log, or documented in another manner.

The inspection programme shall be based on a risk analyses. This means that the plan shall be directed towards the elements and parts which are most likely to fail, as well as the elements and parts that will result in the most serious impacts if they fail.

Procedures for inspection shall be so well described that competent personnel shall be able to perform them without access to other information than that given in the handbook. A description shall be given of what type of competence is required of personnel performing the various types of inspections.

At a minimum, the following shall be included:

a) inspection after change of a main component, any assembly of a new marine finfish farm;

b) inspection after change of a main component with impacts for the other main components and the capacity of the whole of the marine finfish farm;

c) regularly scheduled periodic inspections;

d) inspection or testing for specially defined purposes or by specially defined equipment;

e) inspection after a storm or other serious weather event, e.g. winds greater than 80 km/h

The inspection program shall be related to the parts list. All parts in the overview shall be marked with what type of inspection they require and how often this shall take place.

5.4 Documentation of site inspections and site reports, measured parameters, calculations, and conclusions

All information which characterizes the site shall be presented so that the user can utilize it easily. All procedures shall be described or contain references to a separate description. The connection between

processed data and supporting raw data and additional information shall be explicit. The documentation shall record the following, where this is relevant:

a) instruments;

b) data collection and data processing;

c) data editing and quality control;

d) data quality.

An inspection of the site shall be documented through a separate site report.

Documentation of site owner/operator inspections and repairs performed shall be stored in a systematic and accessible manner in order to ensure traceability.

6 Environmental conditions

6.1 Requirements for determination of environmental conditions

6.1.1 General

Meteorological and oceanographic measurements should be performed on empty sites prior to development (i.e. a site without an installation), if possible. Use of data collected at nearby meteorological stations, nearby wave buoys, or other available sources is encouraged. Metocean data shall be collected and interpreted using established methodologies and standards (e.g. ISO 19901-1).

The 10-year and 50-year return period extreme current, wave, and wind conditions for a marine finfish farm site shall be determined. Values for current speed, wave height and dominant period, and wind speed shall be determined in as many directions as are appropriate to thoroughly assess the site in question (typically, a minimum of at least eight directions). The following clause reviews guidelines for establishing these values.

An assessment of the environmental conditions at the site shall be conducted by a sufficiently experienced and qualified person or organization. A report summarizing the metrological and oceanographic (metocean) assessment shall be produced and will form the basis of the assessment of the suitability of main components and site design as described in Clause 7.

6.1.2 Wind

6.1.2.1 General

ISO 19901-1, EN 1991-1-4, or equivalent shall be used in order to determine the wind velocity for calculation of wind-induced waves.

To determine wind velocity for calculation of the wind load on barges, extra equipment or ice-covered marine finfish farms, ISO 19901-1, EN 1991-1-4, or 6.2.2 shall be used, with a 50-year return period.

6.1.2.2 Use of wind data from meteorological stations

When data from meteorological stations are used, measurements from the nearest or the nearest two meteorological weather stations should be used. Long-term statistics should be prepared if they are not available from the meteorological weather station's data. Long-term statistical mean wind velocity shall be determined with a return period of 10 years and 50 years respectively.

Use of wind data from weather stations should always be accompanied by a documented assessment of the site in question in relation to the weather stations. Elements which should be taken into consideration are the distance between weather stations and the site, degree of sheltering of the site in relation to the weather stations, and critical wind directions.

6.1.3 Current

6.1.3.1 General

The variation of current velocity with depth at the site shall be determined. The maximum current velocities shall be determined. Either 6.1.3.2 or 6.1.3.3 should be considered in determining current velocities.

Measurements shall be taken at a location at the site which is expected to have the highest current velocities and shall be representative of the areas where the finfish farm is to be located. The measurement site shall be indicated and justified.

Collection of current velocity data entails recording the time of the measurement, the current velocity, and the current direction during the whole of the measurement period. Current measurements shall take place in accordance with accepted procedures, dependent on the bottom depth of the site and exposure.

Measurements are typically made at a minimum of two levels for marine finfish farm site characterization, 5 m and 15 m respectively below mean sea level, where topography permits. The logging frequency should be at least every 10 min. Previous measurements which are available and have been logged at longer intervals (e.g. 30 min) can be used when the data has been collected over longer periods of time (e.g. a complete year) and can be collated. Appropriate statistical analysis should be applied. Care should be taken to collect enough current data at a sufficient number of depths to accurately determine hydrodynamic loading on floating collars, net cages and moorings.

NOTE It is sometimes considered necessary to also measure at depths below 15 m below mean sea level and also depending on the type of marine finfish farm.

The critical current components that contribute to the total current overview that should be assessed for the site are:

a) tidal current;

b) wind induced surface current;

c) outbreak from the coastal current;

d) spring flood because of localized events such as snow and ice melt or heavy rains.

Quality assessment of measurement data of current measurements shall be performed, and include

— reliability of data, and

— factors during the measurement period that can have affected the measurements.

6.1.3.2 Measurements of current for one year and use of long-term statistics

Data for current velocity shall be obtained by measurements of at least 12 months duration at the site. The data shall be processed by using harmonic analysis with subsequent harmonization of long-term statistics. It is possible to assemble several partial measurements of at least 4 weeks' consecutive duration which together cover one calendar year.

6.1.3.3 Measurement of current for one month

If it is not possible to obtain measurements for a duration of 12 months, the current velocity should be adjusted to ensure conservative design. If the highest current velocity with a return period of 50 years, based on a measurement over one month is lower than 50 cm/s, the current velocity (50 years' return period) at the site shall, regardless, be set at 50 cm/s.

6.1.3.4 Use of previous current measurements

Existing current measurements may be used if they meet the requirements stated in this International Standard. Measurements at other depths than those specified may be used, provided that it is possible

to use them to estimate the current velocity at the stated depths by interpolation. Interpolation between strata should take into account that the current can present strong variations between water depths and produce reversal directions between two neighbouring layers in estuarine areas such as located in fjords and channels.

6.1.4 Waves

6.1.4.1 General

The wave height versus wave period relationships for the design sea state should be accurately determined from oceanographic data for the area of operation using standard methods. As many marine finfish farms are in protected locations, wave height and period can be determined using wave induced wind formulae provided in this section.

6.1.4.2 Wind-induced waves

The method for determination of waves shall be documented. Wind-induced waves shall either be determined by wave measurements or by calculation.

In addition to the methods described below, a wave chart can be based on long-term wave measurements if they cover the relevant site.

Quality assessment of the measurement data of wave measurements shall be performed, and shall include

a) reliability of data, and

b) factors during the measurement period that can have affected the measurements.

Wind-induced waves may be calculated based on wind data from 6.1.1 and fetch length measured on a hydrographic chart. Significant wave height can be determined based on effective fetch length and 10 min average wind at 10 m height, and such that the wave height increases (approximately) proportionally with the wind velocity and proportionally with the square root of effective fetch length. The 50-year and 10-year return period wave conditions would be determined based on the site's 50-year and 10-year wind condition.

Calculate the adjusted wind velocity U_A using the wind velocity U_{10} (m/s):

$$U_A = 0{,}71 \cdot U_{10}^{123} \tag{1}$$

Significant wave height H_s and equivalent peak period in the wave spectrum T_P as well as effective fetch length F_e are given by:

$$H_s = 5{,}112 \times 10^{-4} \cdot U_A \cdot F_e^{1/2} \tag{2}$$

$$T_P = 6{,}238 \times 10^{-2} \cdot (U_A \cdot F_e)^{1/3} \tag{3}$$

Effective fetch length shall be found by the use of a recognized method and used together with an angle opening of maximum ±12°. Peak period and dimensioning, significant wave height are found by using the formulae stated above.

6.1.4.3 Ocean swells

An assessment should be made and documented of whether ocean swells occur at the site or if the site is influenced by ocean swells. If so, the wave height and peak period should be determined using accepted methodologies, such as

a) numerical modelling (diffraction and refraction analysis), and

b) measurements.

In the case of ocean swells at the site, the combined sea state shall also be determined by combining calculated ocean swells with calculated, wind-induced waves.

6.1.4.4 Other wave conditions at the site

The following effects shall be assessed to see how far they can affect the wave spectrum: ship-generated waves, wave reflection (such as if the site is located near a steep mountainside or similar), effect of several wave trains (such as if two fjord systems meet or by combination of wind-induced sea and ocean swell), and wave and current interaction (changes of wave spectrum at the site with a lot of current).

These conditions can contribute to changing the wave spectrum in the form of an increased significant wave height or changed peak period. The result of the analyses can lead to providing several wave spectra for the site.

6.1.5 Ice and snow

Ice and snow conditions at the site shall be assessed based on recognized methods.

6.1.6 Water depth and bottom bathymetry

The bathymetry and substrate type at bottom attachments and along seabed mooring lines shall be charted. Bottom depth in the relevant area for the marine finfish farm, including mooring, should be charted in a grid with a maximum of 10 m × 10 m between the registered points. Large irregularities on the extent of anchors intended for use, such as large stones, spines, fissures or larger objects, should be noted.

6.1.7 Water chemistry parameters

Temperature and salinity should be determined and monitored when relevant.

6.2 Use of environmental conditions for design of marine finfish farms

6.2.1 General

The data reported in the meteorological and oceanographic assessment of the marine finfish farm site shall be used as the basis for determination of the marine finfish farm design conditions. Appropriate care when using the wind, wave, and current data should be exercised to ensure a conservative design. ISO 19901-1 should be referenced when determining how to interpret and apply the environmental data to the design of the finfish farm; the standard contains detailed information about accepted environmental modelling strategies.

6.2.2 Wave modelling

6.2.2.1 Irregular sea

When modelling an irregular sea for the design of a marine finfish farm, experience has shown that the JONSWAP wave spectrum can be used with $\gamma = 2,5$ for wind driven seas in protected areas. In exposed areas, a JONSWAP spectrum should be used with $\gamma = 6,0$ for open ocean swells. Alternatively, in fjords and sheltered sites, a 2-parameter PM spectrum (Pierson Moskowitz spectrum) can be used. A fully developed sea state can be assumed to ensure conservative results.

6.2.2.2 Regular sea

When modelling a regular sea for the design of a marine finfish farm, the regular wave height H_{regular} used for design and dimensioning situations should be the maximum expected wave height, which can be estimated from the significant wave height as:

$$H_{\text{regular}} = 1,9 \cdot H_s \tag{4}$$

Regular wave period shall be set at the peak period T_P.

6.2.2.3 Cold weather considerations

Danger of icing, drift ice, and the effects of freezing over on the marine finfish farm and attached and affixed equipment should be assessed. Factors should be considered on the basis of the following meteorological data for the site:

a) air temperature;

b) wind and predominant exposure to wind;

c) waves and exposure to waves;

d) sea temperature;

e) salinity;

f) expected precipitation, including proportion expected as snow and freezing rain;

A mass density of ice of 850 kg/m^3 shall be used unless otherwise documented.

Determination of ice and icing potential shall be done based on recognized methods. Previous and possible experiences regarding the site shall be included in the assessment.

The period for continuous accumulation of ice shall be assessed based on the possibility of removal of ice and documented measures for icing prevention. If nothing else is documented, three 24-h periods shall be used.

The danger of drift ice at the site shall be assessed and documented. An indication shall also be given of which parts of the year drift ice can occur. The assessments shall be performed based on meteorological data and likely sources including local knowledge.

The danger of the surface water freezing over at the site shall be assessed and documented, with an indication of a possible time of year that this can occur. This shall be performed by assessing meteorological data compared to local knowledge of the site.

7 Design of marine finfish farms

7.1 General

The owner/operator of a marine finfish farm must select equipment suitable for use at a particular site. The suitability of the main components chosen for use at the site must be assessed by experienced and qualified personnel. The interaction of the components should be assessed to minimize the risk of fish escapes and increase safety. The following chapter provides requirements on the design and assessment of marine finfish farms as a whole and the main components.

The general principles for the design and assessment of marine finfish farms closely parallel those developed for offshore and marine industries. ISO 19900 provides guidance and presents basic principles on the design of marine structures that can be applied to this International Standard. This International Standard provides basic information on the principles of limit state design. Standardized safety factor

based approaches (such as those used by the American Petroleum Institute – API) may be applied, provided an equivalent level of safety is achieved.

Where such specific standards on the design of unique elements of marine finfish farms are not applicable, engineering and scientific publications should be used by the designer or manufacturer to determine appropriate methods of analysis.

7.2 General considerations

7.2.1 Selection of floating collars

Floating collars are typically constructed of HDPE or galvanized steel in combination with plastic or foam flotation. These structures should be designed following accepted approaches for the analysis of marine structures, such as those presented in the ISO 19900- series.

Numerical modelling of floating collars using finite-element analysis or similar approaches are encouraged where experienced personnel can assess the validity of the solution. Validation of analyses should be completed where uncertainty about modelling parameters or methods can lead to unintended results.

The owner/operator of a marine finfish farm/site should obtain from the manufacturer or supplier of a floating collar a summary of the design approach taken and the environmental design parameters for the floating collar. Key dimensions and mass properties required for global/mooring analysis of the marine finfish farm should be acquired.

7.2.2 Selection of net cages

Net cages and predator nets should be constructed according to regionally developed best practices to prevent fish escapes and predator access. Manufacturers should apply quality control systems to ensure a consistent level of human /equipment safety. Manufacturers should apply quality control systems to ensure a consistent level of safety.

7.2.3 Global analysis of marine finfish farms

The mooring and anchoring systems and the interaction of the main components should be assessed using dynamic or quasi-static analysis approaches.

The effects of nets, compensator buoys, mooring line properties, and interaction with the ocean substrate should be considered.

7.2.4 Barges

Feed, supply, and operations barges should be designed according to accepted standards (DNV, ABS, Lloyds, or equivalent). Barge mooring systems should be assessed using standard approaches.

7.3 Guidance on the design and global analysis of marine finfish farms

7.3.1 Loads and interface between main components

Environmental loads which act on the main components shall be considered. Loads, under which the main components (mutually) act on each other under all conditions at the site, shall be considered.

a) Forces from rafts on the floating collar(s) shall be within the tolerance limits for the latter.

b) Net drag from the net cage on the floating collar shall be within the tolerance limits for the latter.

c) Horizontal and vertical forces from the mooring on the floating collar shall be within its tolerance limits.

d) Forces on the floating collar from the mooring shall not transfer moments to the floating collar that will damage the floating collar.

e) Horizontal and vertical forces from the floating collar on moorings, including additional forces from the net cage and raft, shall be within the tolerance limits of moorings, including the capacity of the bottom attachment.

f) Forces from the floating collar on the net cage shall be within the latter's tolerance limits under all environmental conditions.

g) Forces from the predator nets on the mooring systems and or floating collar shall be within the latter's tolerance limits under all environmental conditions.

7.3.2 Load and load combinations

7.3.2.1 Dimensioning situations

A marine finfish farm shall be designed and constructed so that farming can be carried out while minimizing the event of farmed fish escaping as a result of technical failure. The designs and construction situations shall be sufficient to address the relevant circumstances which can occur during installation, operation, repair, and maintenance of the marine finfish farms.

The following sequences shall be included in a dimensioning analysis:

a) determination of the loads;

b) determination of impact of the loads;

c) determination of resistance and response to the effects of loads;

d) control in relation to defined limit states.

It shall be proven that the marine finfish farm functions as intended and designed in limit states to a sufficient probability. Design shall be done in relation to two limit states:

a) serviceability limit state;

b) ultimate limit state.

Fatigue and accident situations shall be seen in regard to the ultimate limit state. The limit states shall be handled in accordance with ISO 19900.

7.3.2.2 Loads

All load categories which can occur during the design working life of the marine finfish farm, shall be assessed and documented. These loads can be classified into the following categories:

— permanent loads;

— variable function loads;

— deformation loads;

— environmental loads;

— accidental loads.

The permanent loads represent loads which will not be removed during the design working life of the marine finfish farm.

Variable function loads are maximum user loads which can be removed or relocated. Deformation loads are loads which occur at forced deformation. This includes deformation which is due to the function or to circumstances in the surroundings.

Environmental loads on the farm are loads which are applied to the marine finfish farm by environmental circumstances, such as wind, current and waves. Regional dependent environmental loads, for instance ice loads, shall also be considered.

To account for the increased drag on the net, a 50 % increase of the twine diameter of the net shall be used in the calculations for drag loads, unless it can be documented that no fouling will occur on the net.

As a minimum, accidental conditions/damage conditions shall be calculated, assessed, and documented, and their impact shall be evaluated. This includes conditions such as

a) breaks in mooring lines, and

b) puncturing or loss of floating parts.

7.3.3 Breaks in mooring lines

A marine finfish farm shall be assessed for breaks in the mooring system. Progressive breaks shall be especially assessed. Breaks in each line shall be assessed. Breaks which weaken the stability of the mooring and functionality of the floating collar shall be assessed.

In particular, an assessment shall be made and documented, and if necessary supported by calculations, of breaks in the following:

a) breaks in lines carrying the largest load;

b) breaks in lines which are critical for strength in the marine finfish farm, especially the floating collar;

c) breaks in the connecting points, such as coupling disc. Possible breaks in connecting points (including coupling discs) will vary based on the design of the connecting point. The break/tear form which gives the least capacity shall be regarded as broken. If the connecting point has probable break sections which entail that several mooring lines are out of function, this shall be regarded as accidental load;

d) breaks in lines that are critical for positioning of single or groups of cages with common moorings, where relocation can lead to damage to adjacent cages.

7.3.4 Puncturing

Marine finfish farms must be designed such that the following situations will be within the tolerances established:

a) water penetration in one floating element or between two bulkheads (when using hollow floating elements);

b) loss of one floating element at a most critical place (when using floating elements filled with buoyancy materials).

7.3.5 Load factors

For load calculations, the load factors in Table 1, Table 2, and Table 3 shall be used.

Table 1 — Load factors for floating collars and barges of steel, concrete and plastic in an ultimate limit state

Design situation	Permanent load	Variable functional load	Deformation load	Environmental load
Establishment of floating ability	1,0/0,9[a]	1,0	1,0	1,0[b]
Establishment of capacity	1,0	1,0	1,0	1,3
Accident situation — Damaged condition[c]	1,0	1,0	1,0	1,0

[a] Favourable load (buoyancy) and unfavourable load (weight) shall be regarded as separate loads. The favourable part has a load factor of 0,9, and the unfavourable part has a factor of 1,0.

[b] Applies to loads from ice and snow.

[c] Applies to breaks in mooring lines, puncturing.

For serviceability limit states, all load factors are set at 1,0.

The values in Table 1 are used in dynamic analyses. In the event of quasi-static analysis, the stated load factors in Table 1 are multiplied by a dynamic amplification factor greater than or equal to 1,1. The basis for the chosen factor shall be justified and documented. In order to establish the dynamic factors, it is necessary to know the resonant frequencies of the construction and the load's variation in time and space. The analyses shall be performed in accordance with EN 1990.[18]

Table 2 — Load factors for mooring lines

Type of analysis	Load factor
Quasi-static analysis	1,15 × DAF[a]
Dynamic analysis	1,15
Accident limit state	1,0

[a] A factor of 1,15 multiplied by dynamic amplification factor (DAF) is used. Dynamic amplification factor ≥ 1,1. Choice of value of DAF shall be justified and documented.

Table 3 — Load factor for rope in net cages

Various components	Load factor
Net pen, dimension Grade 0	1,3
Net pen, dimension Grade 0, manual lifting equipment	1,5
Net pen, dimension Grade 0, mechanical lifting equipment	3,0

7.3.5.1 Load combinations

Table 4 indicates combinations of current, wind and waves for controls in ultimate limit states.

Load combinations are most sensitive to wave angle. The combination of wave, current and periods is site dependent.

Table 4 — Combinations of environmental loads

Combinations	Return period, environmental load year		
	Current	Wind	Wave
1	50	10	10
2	10	50	50

For controls in serviceability limit states, a reduction factor, ψ = 0,7 is used for the loads in Table 4.

Table 4 indicates combinations of current, wind, and waves for control in ultimate limit states. In accident limit states, the individual events shall be controlled under stress from the most unfavourable of the two environmental load combinations in Table 4. An assessment shall be made of which environmental load combination is the most unfavourable for each accidental event.

7.3.5.2 Load calculations

The main components shall be dimensioned according to calculations regarding waves, wind, and current in eight directions, as specified in Clause 6. Single parts or main components or joining of single parts to the main components shall be dimensioned to tolerate the forces applied to them.

Dimensioning shall take into consideration mutual influence between the main components, such as between the floating collar and net cage, floating collar and mooring, floating collar and raft, net cage and mooring, net pen and raft, mooring and raft, and between the main components and any extra equipment.

The main components shall be calculated in relation to probable configurations/connections with other main components. Documentation of possibilities and limitations in the use of equipment as a result of these calculations shall be available.

7.3.5.3 Calculation of the effects of load

Construction calculations shall be based on a suitable choice of stress-strain conditions for materials and connections. In general, it is assumed that the constructions will be linear elastic. Non-linear models can be used where indicated in the planning standards for the various materials.

7.3.6 Design working life and durability

The design working life shall be determined for both the whole of the marine finfish farm and its main components.

The planning objective shall be that finfish farms remain suitable for use during the determined useful life. In order to ensure sufficient durability, the following shall be taken into consideration:

a) use area is finfish farming, without the escape of farmed fish;

b) functional requirements in this International Standard;

c) maximum environmental forces the marine finfish farm withstands;

d) composition, characteristics and performance of the materials;

e) choice of load-bearing system;

f) design of the parts and constructive detailing;

g) requirements in regards to skilled work requirements, both during production and operation;

h) scope of inspections;

i) defined protection measures;

j) inspection and maintenance procedures during operation for the entire design working life.

Planning and mooring shall also take into consideration the seabed conditions, including depth, topography and seabed substrate, on the basis of the results of the site survey.

7.3.7 User handbook and global analysis documentation

A report shall be prepared that outlines the results of the global analysis of the marine finfish farm.

The user handbook (reviewed in Clause 5) shall contain the following information regarding design working life and associated requirements, and requirements for inspection and maintenance procedures.

a) Design working life which is used as a basis for the calculation and design shall be stated and procedure for monitoring the life time should be documented;.

b) Description of the environmental loads which the main component shall tolerate, at a minimum loads from wind, current, waves, temperature, and other relevant regional environment loads (such as ice).

c) Description of the functional loads which the main component is designed for, particularly connected to direct operation of the marine finfish farm installation, such as load from equipment, feed, personnel, etc.

d) Description of the permanent loads on the floating collar in the form of weight/buoyancy and the distribution of them on the collar.

e) Description of accidental loads, such as negative loads because of breaks in the mooring lines and loss of buoyancy.

f) Describe any limit conditions or important assumptions made in the design (for instance size, weight, solidity of the net cage, maximum net cage drag and attachment of the net cage to the floating collar).

g) All material parameters in capacity, strength, and design calculations shall be available and refer to the source (such as supplier documentation), or what reasoning, method or calculations they are based on.

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