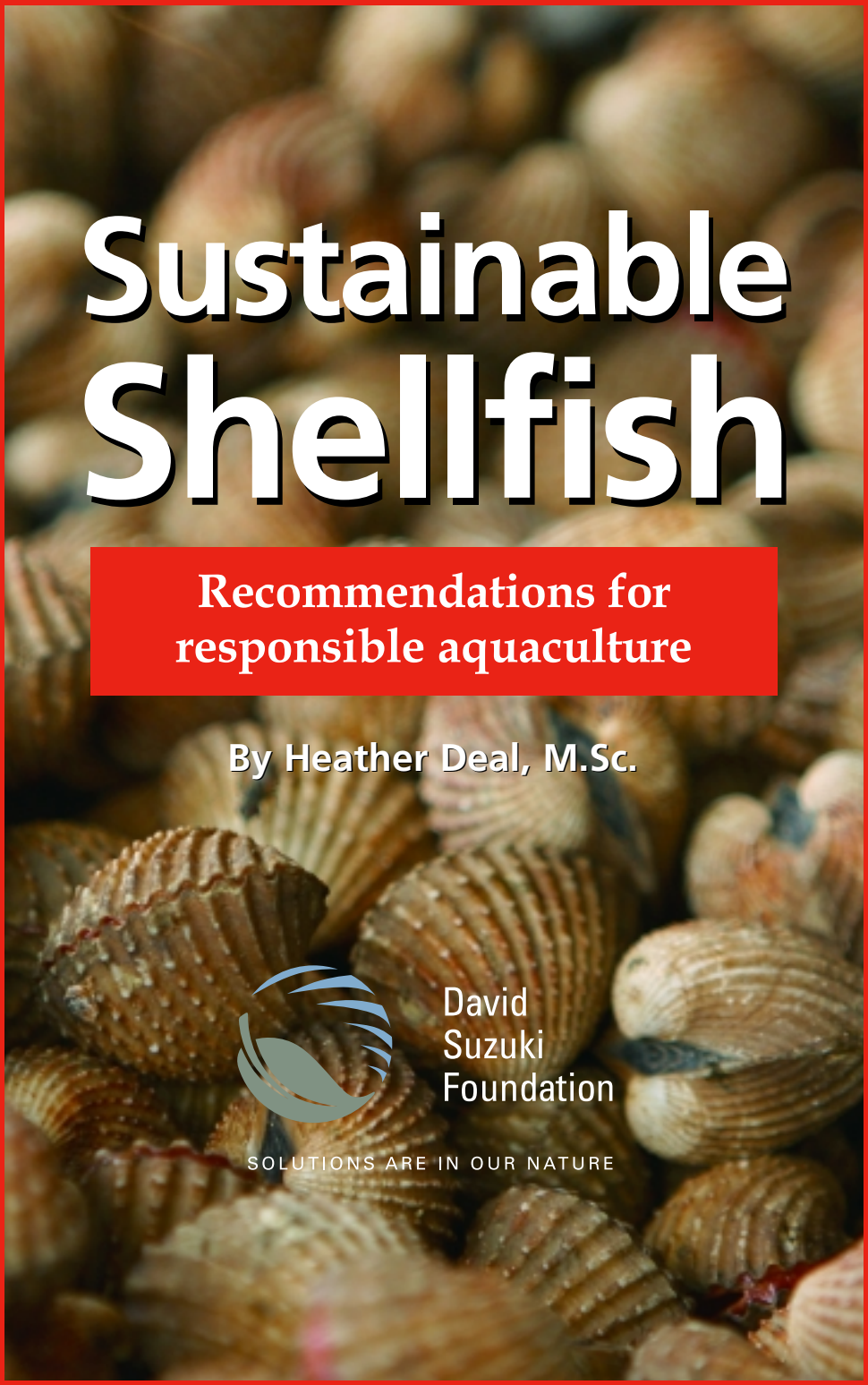

Sustainable
Shellfish
Recommendations for
responsible aquaculture
By Heather Deal, M.Sc.
David
Suzuki
Foundation
SOLUTIONS ARE IN OUR NATURE

As *Sustainable Shellfish* went to press, the B.C. Ministry of Agriculture, Food and Fisheries (MAFF) pulled their draft *Code of Practice for Shellfish Aquaculture* from circulation. This document, upon which much of *Sustainable Shellfish* is based, was one component in guiding, monitoring, and regulating B.C.'s rapidly growing shellfish industry. The *Code* was by no means exhaustive – *Sustainable Shellfish* aims to address its gaps and limitations, including its lack of consideration for stringent environmental safeguards on the expanding industry.

Now that the *Code of Practice* has been abandoned by government, the shellfish industry is managed via complaints to the Farm Industry Review Board. This board uses "normal farm practices" as a standard, but does not and, according to MAFF, will not define what "normal farm practices" are with regard to aquaculture. In other words, although there is legislation in place, there are no longer governmental standards or guidelines specific to this industry.

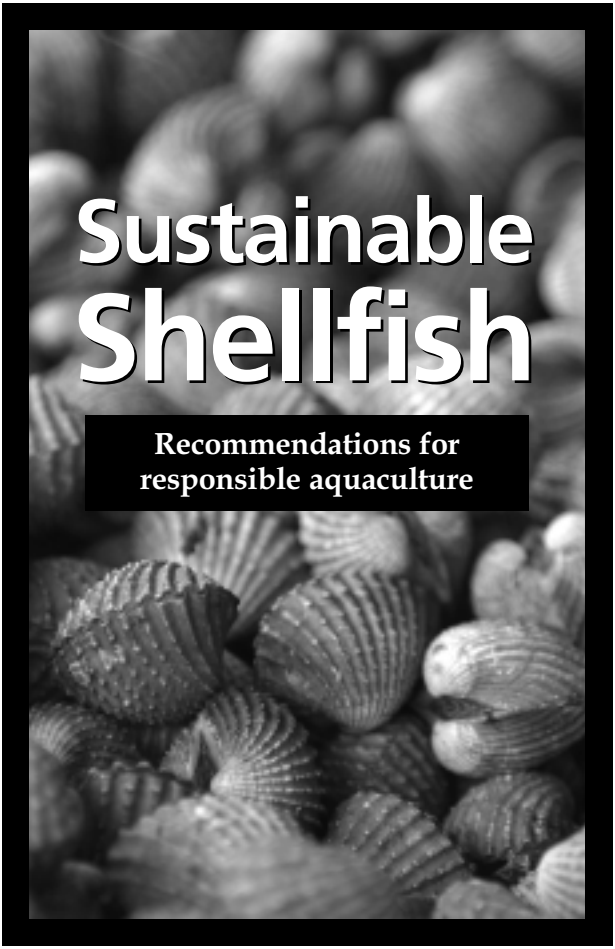
The BC Shellfish Growers Association (BCSGA) does have an Environmental Management System and Code of Practice, which is very similar to that which MAFF produced. The BCSGA Code is not available on their website, so please contact the association directly to request a copy:

#7 - 140 Wallace Street
Nanaimo, BC V9R 5B1
Tel: (250) 714-0804
Fax: (250) 714-0805
Email: info@bcsga.ca

The draft government *Code of Practice* is still available on the David Suzuki Foundation website,

www.davidsuzuki.org/oceans.

Sustainable Shellfish, used in conjunction with the non-operational *Code* offers a way forward towards a low impact industry with minimal harmful effects on B.C.'s marine environment and coastal communities.



**A report by Heather Deal for the
David Suzuki Foundation**

David
Suzuki
Foundation

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The following people and organizations contributed to this Guide, either by adding to and/or reviewing the contents, by providing photographs, or by inviting the author to join them on shellfish operations. There were a variety of opinions expressed regarding the material in the guide. Appearance of a name in these acknowledgements does not necessarily indicate an endorsement of the Guide.

BC Shellfish Growers Association

Dr. Leah Bendell-Young *Department of Biological Sciences, Simon Fraser University*

Jennifer Brown *Communications Specialist, David Suzuki Foundation*

Rob Butler *Senior Research Scientist and Professor (Adjunct), Canadian Wildlife Service*

Bart DeFreitas *Program Biologist, Haida Fisheries*

Paula Doucette *Assessment Biologist, Fisheries and Oceans Canada*

John Harper *Coastal and Ocean Resources Inc.*

Otto Langer *Director, Marine Conservation Program, David Suzuki Foundation*

Brad Mason *Senior Habitat Inventory Biologist, Fisheries and Oceans Canada*

R. McKelvey *Canadian Wildlife Service*

Jim Mitchell *Marine Campaigner, Quadra Group, Sierra Club of Canada, BC Chapter*

Stefan Ochman *Fisheries Manager, Huu-ay-aht First Nation*

Josie Osborne *Nuu-chah-nulth Tribal Council Fisheries Program*

Cathy Slater *Shellfish Farmer*

Suzanne Tank *Fisheries Biologist, David Suzuki Foundation*

Bill Wareham *Acting Director, Marine Conservation Program, David Suzuki Foundation*

Watershed Watch Salmon Society

Christianne Wilhelmson *Clean Air and Water Program Coordinator, Georgia Strait Alliance*

David Suzuki Foundation
219 - 2211 West 4th Avenue, Vancouver, BC Canada V6K 4S2
Tel: 604-732-4228 • Fax: 604-732-0752
www.davidsuzuki.org

A copy of this report can be obtained on the David Suzuki Foundation website.

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Introduction

Shellfish have been cultivated by people along the British Columbia coast for centuries. Over the past century, shellfish farming has become a commercial undertaking. More recently, operational techniques have evolved and the scale of many operations has increased dramatically. Today, the B.C. shellfish aquaculture industry is well established and growing, with over 400 current leases along the coast. Many of these are operated by members of the B.C. Shellfish Grower's Association.

More growth is expected due to recent changes in provincial commercial shellfish policy. In 1998, the B.C. government launched a plan that would double the Crown land available for shellfish farming by 2008. In addition, recent changes to the *Farm Practices Protection ("Right to Farm") Act* may make it possible to intensify aquaculture practices regardless of the wishes of local governments and communities. These initiatives, combined with a high level of interest in establishing shellfish farms along the central and north coasts of B.C., will likely result in significant growth in the B.C. shellfish aquaculture industry in the coming years.

Traditionally, commercial shellfish production has a minimal known effect on other coastal marine resources. The fact that it requires clean water, doesn't use introduced food or chemicals and produces little waste mitigates some potential impacts.

However, there is some cause for concern. Most commercially farmed shellfish species are non-native, and alien to the B.C. coast. Furthermore, the industry is becoming more intensive and aquaculture operations are moving into new regions. It is this intensification and geographic expansion that is raising concerns regarding marine ecosystem health. Great caution must be exercised to avoid potential environmental damage, including alteration of marine bird nesting, feeding and migrating habitats, disruption of intertidal water and substrate movement, depletion of microorganisms in the water column and decreasing biodiversity brought about by cultivating single species.[1]

Chapters II – IV of this guide outline its objectives and address several key concerns surrounding B.C.'s shellfish aquaculture industry. The remainder of the guide outlines some operational recommendations to assist shellfish farmers in keeping the effects of their operations as envi-

ronmentally benign as possible. It lists concerns and recommended practices specific to shellfish aquaculture methods commonly in use in B.C.

These recommendations were produced through a combination of:

- Scientific literature review
- Field visits, and
- Consultation with scientists, shellfish growers and three levels of government (First Nations, federal, provincial).

There are several independent scientific studies currently underway which examine the potential impacts of shellfish aquaculture on ecosystems and other organisms. There are many more questions yet to be addressed. All precautions and practices should be altered as new scientific information becomes available.

Shellfish farmers should have a strong knowledge of foreshore ecology.

Objectives of this guide

The following shellfish aquaculture guidelines are currently available through the Department of Fisheries and Oceans, (DFO) the B.C. Ministry of Agriculture, Fish and Food (MAFF) and the B.C. Shellfish Growers Association (BCSGA). These documents are referenced throughout this guide:

- DFO *Interim Guide to Information Requirements for Environmental Assessment of Marine Shellfish Aquaculture Projects (2003)*[2]
- DFO working draft of *Marine Foreshore Environmental Assessment Procedure (2002)* (currently focused on fin fish aquaculture)[3]
- B.C. Ministry of Agriculture, Food and Fisheries *B.C. Shellfish Aquaculture Code of Practice (Final Submission July 2002)*[4]
- B.C. Shellfish Growers Association *Environmental Management Code of Practice (2001)*[5]

There are additional resources available with related information regarding human activity in shoreline ecosystems:

- *Access Near Aquatic Areas:A Guide to Sensitive Planning, Design and Management (1996)*[6]
- *Shoreline Structures Environmental Design: A Guide for Structures along Estuaries and Large Rivers (2003)*[7]
- *Coastal Shore Stewardship: A Guide for Planners, Builders and Developers (2003)*[8]

The objective of this guide is to augment the documents above with recommendations for how to minimize potential and eliminate known negative environmental impacts caused by the shellfish farming industry and to emphasize a cautious approach to farming techniques and practices. All provincial and federal siting regulations apply, and are listed in the referenced documents. These recommendations, while focused on environmental issues, acknowledge that there are broader social, legal and economic issues as well.

This guide addresses issues related to the most common shellfish species and practices in B.C. Other species and methods currently in limited use

are not specifically addressed, although the principles in this guide can be applied.

In addition to following these guidelines and recommendations, shellfish farmers should have a strong knowledge of foreshore ecology. This can be gained through experience, traditional knowledge and/or training and education. This knowledge should include an understanding of the biology, structure, function, and processes of intertidal and nearshore zones. A good understanding and appreciation of the ecology of a proposed farm site can lead to higher productivity, less effort for the same product, fewer risks and fewer negative impacts.

photo: Leah Bendell-Young

This is an example of beach culture which will significantly change the natural movement of substrate in the intertidal area.

Principles and issues related to shellfish aquaculture

There are several concepts which apply ecological principles to human activities, including shellfish aquaculture. This section defines and discusses these concepts and introduces some overarching concerns about shellfish aquaculture.

1. Precautionary principle

The precautionary principle is an approach to human activity that attempts to minimize potential damage to the environment. In 1992, this definition appeared in Section 15 of the Rio Declaration:

…Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

In 2001, DFO produced a discussion paper on the precautionary principle that referenced the following definition:

The precautionary approach/precautionary principle is a distinctive approach within risk management that primarily affects the development of options and the decision phases, and is ultimately guided by judgment, based on values and priorities.[9]

Perhaps the most practical definition of the precautionary principle is:

…in the face of uncertainty, the best course of action is to assume that a potential problem is real and should be addressed ("better safe than sorry").[10]

Shellfish farming is assumed by many to be an environmentally benign industry. However, some practices will result in negative impacts as farming intensifies and expands. For example, anti-predator netting on a small portion of the sandy beaches of a migratory bird route may not have a measurable effect on feeding habits, but if larger areas of the beaches are covered, birds may be deterred from

using that area. A few rafts in an enclosed bay might not significantly decrease the amount of food available for wild filter-feeders, but large numbers of rafts could severely decrease food availability for some organisms.

Unfortunately, many of the basic scientific studies that are required to understand the impacts of shellfish farming have not been completed, and few studies of long-term impacts are being undertaken. Applied to shellfish aquaculture, the precautionary principle guides operators to minimize known or probable impacts until research is completed. Recommended applications of the precautionary principle are included throughout this guide.

2. Ecosystem-based management

Ecosystem-based management (EBM) is a term used to describe a holistic way of managing resources while taking the surrounding ecosystem into account. There is no one definition of EBM, but this early definition has stood the test of time and is widely quoted:

> *…ecosystem management is integrating scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward the general goal of protecting native ecosystem integrity over the long term.*[11]

Achieving EBM requires many components, including:

- Appropriate management areas (large enough to represent ecological systems),
- Appropriately sized protected areas,
- Mitigation strategies for potential long-term impacts,
- A conceptual model of the food web within each ecosystem (used for making predictions of future impacts),
- Description of the habitat needs for each of the life history stages of all plants and animals contained in the above food web, and
- Measurable indicators of ecosystem health as targets for management.[12]

DFO's Oceans Strategy explicitly commits to application of the precautionary principle and **ecosystem based management** principles to address the exploitation of marine resources.[13] Yet at a 2003 conference in Korea, a session on marine EBM stated the following:

> *Many recent national and international legal agreements use some form of the term 'ecosystem-based approaches' when describing new methods to assess and manage marine living resources. These are usually understood to include objectives related to maintaining and monitoring biodiversity, productivity, and the physical and chemical properties of an ecosystem. It is often unclear, however, what this means in practice, what new information will be required, and whether scientific or management actions will actually change under these new approaches.*[14]

In Canada, the action points in the Oceans Strategy do nothing to address the need for management in the context of the ecosystem.

Indeed, in Canada the action points in the Oceans Strategy do nothing to address the need for management in the context of the ecosystem. This lack of clarity, especially regarding the appropriate size of area and length of time that must be taken into consideration when EBM is properly implemented, reinforces the need for shellfish farmers to apply the precautionary principle to their practices.

3. Cumulative effects

The cumulative impact of multiple environmental changes is one of the primary issues of concern with an increasing quantity and intensity of shellfish farming. The Canadian Cumulative Effects Assessment Practitioners Guide defines cumulative effects as "changes to the environment that are caused by an action in combination with other past, present and future human actions."[15] It lists some of the disturbances that can lead to cumulative effects, including physical-chemical transport, gradual disturbance and loss of land and habitat, spatial and temporal crowding, and growth-

inducing potential (e.g. increased traffic).[16] Each of these factors can occur in shellfish aquaculture and should be watched for and guarded against. Examples include beach substrate disturbance, increased density of a single species in the ecosystem and increased human activity. The issue of cumulative effects is particularly important, given the shortage of research on impacts of many individual shellfish farming practices.

Examples of impacts that may add to cumulative effects:

- Alteration of beach substrate dynamics:
    - Anti-predator nets
    - Vexar fencing and rock rows
    - Human and vehicle traffic
    - Very high density of oysters on surface and/or clams in the substrate
- Change in ratios of species abundance:
    - High densities of single organism
    - Predators attracted to site
    - Elimination/exclusion of predators
    - Altered ecology under nets
    - Altered ecology under and near rafts
- Human activity:
    - Vehicles driven on beach
    - Night activity
    - Lights and noise
    - Debris

4. Carrying capacity

"Carrying capacity"is a term used to describe the maximum average number (or "biomass") of organisms that can be sustained in a habitat over the long term.[17] Sometimes referred to as the productive

capacity, it is used to determine how much of a plant or organism can be grown in an area before production is affected by lack of space or nutrients.

There are more holistic definitions of carrying capacity, which take into consideration the degradation of the ecosystem these organisms are grown in. Productive capacity studies are being undertaken in several places in B.C. as the shellfish farming industry prepares to expand. These studies are focused on determining the maximum number of shellfish that farmers can grow for profit, rather than focusing on the maximum number that can be grown before significant impacts to the surrounding ecosystem are seen.

There is also a shortage of long-range impact studies that might detect shifts in ecological conditions that don't appear over a short timeline. For these reasons, data concerning the state of the ecosystem should be collected prior to setting up a farming operation, and regular monitoring should be undertaken to detect changes to that ecosystem. It is not sufficient to assume that the maximum number of allowable organisms can be grown without causing significant impacts over time.

5. Biodiversity

Biological diversity, or biodiversity, refers to the variety of and variability among living organisms, and the diversity among the complex ecological processes of which they are a part. It encompasses all of the world's living resources.

The earth's biodiversity forms a foundation for the quality of human life as well as the raw materials that enrich it. The biological diversity represented by living marine resources provides essential economic, environmental, aesthetic, and cultural benefits to humanity.[18] The maintenance of these benefits depends on our protection of the biological diversity of the oceans.[19] This requires not only protection of organisms, but protection of their habitats.

Cultivation of shellfish leads to an increased amount of one or more farmed species in a given area. While increased biomass may seem desirable to some, the delicate ecological balance normally occurring between organisms may be compromised by overabundance of spe-

cific species. Species which live well with an introduced shellfish species will thrive while other species may be unable to compete for habitat or food. Over time, this can lead to decreased biodiversity as a few species come to dominate the habitat. The result is a change in the ecological structure of the ecosytem. Studies from France confirm that long line oyster culture and associated epifauna (mussels and other organisms which grow on the oysters) can significantly affect concentration of oxygen and dissolved nitrogen in the surrounding water column, leading, in some circumstances, to decimation of the benthos. (ocean bottom life)[20] The loss of functioning benthic habitat can in turn lead to the loss of those species which depend on that habitat. The United Nations Environment Programme (UNEP) has identified the introduction of alien species as the second largest threat to global biodiversity (after habitat loss).

6. Non-native species

The Natural Resources Canada publication *Alien Invaders in Canada's Waters, Wetland, and Forests*[21] opens with the following line:

Biological invaders worldwide threaten biodiversity, ecosystem function, economic impacts, resource availability, and human health.

Most farmed shellfish in B.C. are alien species. Some of these species have been present for decades. For example, the Pacific oyster *(Crassostrea gigas)* was first introduced 80 years ago and has largely replaced the native oyster *(Ostrea conchaphila)*. Others, such as the varnish, or savory clam *(Nuttallia obscurata)* were unintentionally introduced as recently as the late 1980's and are already rapidly spreading and colonizing the coast. Efforts are currently underway to establish a scallop farming industry using the Japanese scallop *(Patinopecten yessoensis)* rather than slower-growing native species.

The Mediterranean blue mussel *(Mytilus galloprovincialis)* is an aggressive colonizer that, despite differing spawn cycles and temperature preferences, has been shown to hybridize with native mussels[22] and can displace native species from their habitat[23]. The presence of this highly effective colonizer could lead to the decimation of native populations. In fact, the Mediterranean mussel is on a current list of the most invasive species published by the Global Invasive Species Database.[24] Despite this status and regardless of the Standing

Committee on Fisheries and Oceans 2003 conclusions that "it is now well accepted that invasive species can have a devastating effect on species diversity, …that aquatic invasive species cause significant, negative regional, national and international effects, …[and] that the impact of several invaders is greater than the sum of their effects if they had acted alone"[25], the Mediterranean mussel is being actively promoted for further cultivation along the B.C. coast.

In Western Australia, invasive black-striped mussels are forming monocultures and threatening marine biodiversity. In response to increasing shellfish farm monocultures, the 2002 World Forum of Fisherpeoples includes a clause in their Declaration to the World Summit on Sustainable Development: *21. Protect biodiversity in the marine environment.*[26]

Despite the fact that there is now a federal/provincial introduction and transfers committee, which reviews introductions of alien species, the practice of deliberate introductions persists. The precautionary principle must be applied to invasive species – even if the probability of rampant invasion is low, the risks are unacceptably high.

7. Siting and harmful alterations, disruption or destruction of fish habitat

Siting a shellfish farm appropriately is the most crucial element in planning a successful operation that minimizes impacts. Farmers may wish to choose sites based strictly on the best growing conditions, availability and accessibility. However, due diligence must be paid to the potential for environmental impacts at a given site. For instance, the untested impact of flood lights and noise associated with farming should be taken into consideration when choosing an appropriate site and appropriate level of mechanization for the operation. The provincial guideline for siting addresses operational concerns, but for environmental considerations it refers farmers to the Canadian Environmental Assessment Act (CEAA) and Canadian *Fisheries Act* (Section 35), which prohibits harmful alterations, disruption or destruction of fish habitat (HADD), and prohibits the release of deleterious substances in waters frequented by fish *(Section 36)*. The CEAA guidelines for siting are thorough, and refer to

HADDs throughout. However, DFO, which has the mandate to enforce the *Fisheries Act*, has no clear definition of what a HADD consists of with regard to shellfish farming[27]. Potential HADDs have been identified throughout this guide.

Respecting First Nations rights

The federal government has a fiduciary responsibility to consult with and accommodate First Nations, and it would be in the proponents best interests to consult with and pursue agreements with First Nations when choosing an appropriate site. Concerns may also arise from marine communities such as foreshore property owners, tugboat operators and yachters.

photo: Leah Bendell-Young

This extensive area of anti-predator netting will not only affect intertidal substrate movement, it is adjacent to a stream and will impact the habitat of organisms, such as juvenile salmon, which may rely on the intertidal habitat.

Site and operational considerations

The principles and issues discussed above must be taken into consideration when selecting a site and operating a shellfish farm. Knowledge and understanding of the following factors will help to apply those principles and determine the most productive and least damaging site and operational practices:

1. Water movement patterns

- **How a farm may change them:**
  - *Velocity of flow will change within and around raft and long-line culture*
  - *Water flows will change around beach structures or around densely fenced intertidal zones*
  - *Farm structures create a potential for reduced flushing, which affects water quality*
- **Disease/waste/larval transfer into adjoining areas:**
  - *Flow and current patterns around farm could transfer diseases and or waste and larvae to sensitive nearby habitats*
- **Potential impacts of those changes:**
  - *Organisms that rely on particular water flows and current can have feeding or movement patterns affected*
  - *Water quality changes affects all aquatic organisms, including shellfish*
  - *Sensitive habitats could be damaged by disease or waste*

2. Nutrient levels

- **How a farm may affect them:**
  - *Filter feeders ingest plankton, decreasing levels of primary production*

- *Production of pseudofeces increases nutrient levels in benthic community near farms*
- *Reduced flows can lead to lower flushing levels, and therefore higher nutrient levels*

- **Relationship to water movement patterns**
  - *Higher or lower flows affect nutrient levels throughout water column*
- **Relationship between nutrients and other organisms in the ecosystem:**
  - *Plankton is the primary building block for all marine food webs*
  - *Depletion of plankton can lead to decrease of competing plankton feeders, which are in turn food for larger and more complex organisms*
  - *Those larger organisms, such as herring and salmon, have very high value to humans and ecosystems*

3. Habitat requirements of:

- **Benthic (sea bottom/intertidal substrate) communities of plants and animals:**
  - *Intertidal tenures become dominated by single species in high density, decreasing biodiversity*
  - *Benthic communities under raft cultures can be smothered with pseudofeces*
  - *Predators such as starfish are excluded and sometimes killed*
  - *Biofouling (algae) on netting shades benthic communities and reduces flow over benthic communities*

- **Pelagic (living in the water column) communities of plants and animals, including fish and micro-organisms:**
  - *Clam netting affects algal community in intertidal zone*
  - *Pelagic organisms which feed on benthic organisms are obstructed from their usual food source*
  - *Juvenile fish make extensive use of intertidal ecosystems, where farming takes place*
  - *Intertidal fencing creates a potential obstacle course for fish and other organisms that use the bottom of the water column*
  - *Netting around rafts can impede migratory routes for salmon*
- **Birds:**
  - *Migratory birds feed extensively on intertidal organisms*
  - *Netting can exclude birds from some primary feeding grounds*
  - *Increased availability of single food species affects preferred diet composition*
  - *Netting around rafts to discourage diving birds creates hazard for birds*
  - *Human activity around farms affects feeding, nesting and migration patterns*

photo: R. McKelvey

- **Mammals:**
  - *Animals, such as mink, which feed in the intertidal zone face shifting diet availability and composition*
  - *Rafts, netting under rafts and human activity can impede migratory routes for cetaceans*

Taking the following steps will increase the likelihood of low-impact siting and operations. Siting information, including existing studies, can be found on the MAFF web site[28]. It is not within the scope of this document to define specific methodologies for the following processes:

1. Research suitability of proposed site:

- Where can the most/best product be grown, and
- Where will there be the least damage to existing shellfish, fin fish and other sensitive animals or habitats (any damage is a potential HADD)?
- Is there a plentiful amount of the similar habitat nearby which is available for native organisms in balanced densities? (i.e. don't farm all of the beaches in one area)
- What is proximity to other farm sites, including fin fish farms?
- What is the carrying capacity for the area, not just for shellfish crop but for other pre-existing species and existing ecosystem diversity and balance?

2. Gather baseline information that will help measure change over time:

These measurements should be collected by a Registered Professional Biologist multiple times over a full year to get a true picture of the pre-farming state. Measurements should include:

- Health and composition of benthic community
- Substrate type, location, movement patterns
- Flow regimes
- Diversity and abundance of other organisms in area (birds, invertebrates, algae, etc.)
- Photographs of site from multiple fixed locations
- Water quality measures (as required under the CSSP)
- Primary production e.g. plankton in the water column

3. Monitor changes to local ecosystems on a regular basis (follow-up to baseline measurements:

- Abundance and diversity of species on and near site
- Health and composition of benthic community
- Substrate type, location, movement patterns

- Flow regimes
- Photographs of site from multiple fixed locations

4. Avoid impact of human activity:

- Develop a management plan that includes proper waste disposal and minimal noise, light and beach disturbance, as recommended in the BCSGA and MAFF Codes of Practice.
- Ensure that there is no net loss of fish habitat caused by activity.

photo: Rob Butler

Surf scoters are migratory birds which feed extensively on intertidal organisms.

photo: Heather Deal

High densities of a single bivalve species will change beach biology and dynamics. While these bivalves are mechanically harvested in some places, hand harvesting continues to be the lower-impact method used in B.C.

Recommendations
for specific aquaculture techniques

1. Vehicles

Driving on beaches introduces oil and gasoline to the sensitive intertidal ecosystem, compacts the sand and gravel, and can disrupt the overall form or shape of a beach.

Vehicles should not be used on beaches. Beaching boats or boat propellers can cause similar problems. If driving on a beach is determined not to be a HADD, observe the following precautions:

photo: Heather Deal

Trays with bags of young mussels are lowered from the line. They will mature in the trays.

Recommendations for avoiding damage from vehicle or other heavy equipment use on the beach (can be considered a potential HADD):

- Use a small all-terrain vehicle rather than a truck;
- Choose large and/or under-inflated tires, balloon tires if possible;
- Avoid crushing benthic communities by restricting driving path to bare bedrock or hard sand;
- Choose single access route to minimize the driving area – this also minimizes the damage to shellfish;
- In soft spots, consider laying down temporary materials such as modular tracks or sheets of plywood to drive on – these must be removed afterwards;
- Use boats where feasible, but avoid any impact on the beach
- To prevent substrate disturbance, do not use propellers in shallow water
- If it is necessary to beach, choose hard sand areas
- Keep vehicles, including boats, in good working order and keep a spill kit or an absorptive sheet in the vehicle in case of leaks or spills
- Be aware that Fisheries Act (DFO) authorization is required to alter intertidal substrates, including road creation

See also:

- BCSGA CoP: pp. 30 "Vehicle Operations"
- MAFF CoP: Section 11.0 "Use of Vessels, Vehicles and Marine Equipment"

2. Deep-water and near-bottom culture

Deep-water and near-bottom culture incorporate several techniques, including trays, string culture, tubes, bags and pearl nets. In intertidal operations, bags or cages can be suspended above the substrate on trays. In deep water, trays, tubes, nets or strings are suspended

from longlines or rafts. See the BCSGA website for a more detailed description of these methods and materials.

In general, off-bottom and near bottom oyster/mussel culture techniques should offer an opportunity to reduce environmental impacts. However, some things to be aware of are:

- **Alien species** – Mussels, scallops and oysters currently being farmed commercially in B.C. are alien species, including the primary deep water and near-bottom species. As discussed elsewhere in this guide, there are many reasons to have concerns about the deliberate introduction of alien species for commercial species.
- **High amounts of nutrients on or near bottom sediment** – High densities of rafts for cultivating oysters may lead to large amounts of feces and pseudofeces (bits of undigested food excreted in mucus) in the surrounding waters and on the sea bottom below. This in turn could affect feeding habits and diversity balance of other organisms which rely on consistent nutrient levels. Related studies are underway.
- **Low amounts of nutrients in the water column** – As bivalves are filter feeders, a high density of suspended bivalve culture will decrease the amounts of food available to other organisms in the water column. In addition, the physical presence of suspended aquaculture structures can decrease flow rates, leading to an overestimation of carrying capacity (the limits to what can grow and live in an ecosystem).[30] The B.C. Government has determined that the carrying capacity of Gorge Harbour (Cortes Island) is the number of rafts that would lower the nutrient levels to that of the open water of the adjacent Strait of Georgia. This determination does not acknowledge the importance of localized ecosystems and their nutrient cycles. In addition, coves and other protected waters are key rearing habitat for young fish, so their high productivity must be maintained.
- **Benthic communities** – Feces and pseudofeces will have an impact on the benthic community below, but we do not fully understand the impacts, qualitative or quantitative. In order to address this knowledge gap, there are several studies underway to determine the effects of feces and pseudofeces on benthic communities. High densities and/or extensive areas of deposits of mussels or other

fouling material on the seabed below will affect composition of benthic communities[31] and can eliminate species sensitive to organic enrichment or smothering.

- **Water quality** – Can be affected by cleaning of structures (tubes/trays) on site.
- **Biodiversity** – Monoculture alters natural community composition, potentially lowering biodiversity.
- **Waste disposal** – The footprint of human activity includes the presence of rope ends, everyday garbage like food wrappers, and other waste.

A. Deep water culture (rafts, longline)

- **Structure** – Rafts introduce structure into the marine environment. This additional structure can be viewed as positive in certain environments, as it can support mussels and algae and the communities that will build around them. To interpret this additional structure as a positive effect assumes that the existing state of the surrounding environment can be improved upon by increasing structure and biomass. This is not necessarily true. Making changes to existing states of ecosystems must be avoided, especially when those ecosystems have not been highly altered in the past.


photo: Heather Deal

- **Carrying capacity** – High densities of rafts or longlines in a confined area such as an enclosed bay will have greater environmental effects than lower densities because ecosystems have a limit, or carrying capacity, to what can grow and live within them in a sustained manner over time. If too many oysters are grown in one area or if flows are too low and the carrying capacity is surpassed, not only can there be a significant negative impact to natural marine communities, but cultivated shellfish may be affected as well.
- **Netting** – Some farmers hang nets around string culture suspend-

ed from rafts to prevent predation by diving birds. These nets can prevent birds, mammals and fish from swimming along their normal routes and can result in their death.

- **Tidal flows** – Large numbers of rafts in small areas can alter the effects of wind and water currents, dampen, or reduce, wave action, and alter water dynamics.
- **Shading** – In shallower sites, photosynthetic communities (e.g. eel grass, kelps, etc.) will be affected by shading from multiple rafts over them.

Recommendations for successful deep water culture:

- Do not locate high densities of rafts/longlines in confined bays or inlets with limited flows:
  - High densities should not be permitted in confined or low-flow areas unless comprehensive ecological studies indicate that they can be accommodated by the natural environment.
  - Ensure that related studies, including carrying capacity studies, are done with an ecosystem health focus, not just a shellfish health and productivity focus.
- Ensure that raft and culture materials are:
  - Non-toxic, including wood treatments
  - Disposed of properly
  - Stable/durable in marine environment
- Do not use underwater nets around suspended string culture to prevent predation by birds or other animals (this may be considered a HADD under the Fisheries Act)

See also:

- BCSGA CoP: pp. 36-37 Navigational Safety
- BCSGACoP: pp. 42-43 Equipment and Construction Standards
- MAFF CoP: Section 14.0, p. 16 Navigational Safety
- MAFF CoP: Section 12.0, p. 14 Equipment and Construction Standards

B. Near-bottom culture

photo: Heather Deal

- **Footprint on the beach –** Building vertical structures such as stacks of vexar bags, reduces the horizontal footprint of a farming operation on the beach surface.
- **Natural beach functions –** Building vertical structures in the intertidal zone increases disturbance of beach substrate transport and wave action, which affects nearby shorelines.

Recommendations for avoiding impacts of near-bottom structures:

- Observe and document beach substrate patterns for changes due to structures.
- Move structures on a seasonal basis to allow recovery of the substrate under the structures.
- Adhere to the maximum allowable height of structures on beach.

3. Beach inter-tidal culture

Beach culture is used to grow organisms like clams for both nursery culture and hardening off of oysters. Techniques used include netting to protect young clams, low fences to keep oysters on the farm tenure and bags that sit on or in the beach substrate. See the BCSGA website for more detailed descriptions of these methods and materials.

The following issues must be considered when planning a beach operation:

- **Biodiversity –** Beach culture increases the amount and density of one species beyond the range of its natural abundance. Encouraging the growth of one species while discouraging others decreases biodiversity and disrupts natural community dynamics. Long-term impacts of beach monoculture are not yet fully known,

but are likely to be substantial, as has been found in other ecosystems where monocultures have been established.

Beach culture increases the amount and density of one species beyond the range of its natural abundance.

- **Alien species** – Clams and oysters currently being farmed commercially in B.C. are alien species, including the recently introduced varnish clam (a.k.a. savory clam). This aggressive colonizer is rapidly spreading. Varnish clams have thin shells, making them difficult to harvest intact. Commercial harvest is being encouraged, rather than making every attempt to eradicate them.
- **Beach structure and function** – Any alterations to intertidal zones will change the structure and function of the beach in some manner. Those changes will in turn affect the plants and animals that live there.
- **Sensitive habitats** – The following types of habitats are considered sensitive due to their high ecological value and vulnerability to damage and therefore should not have intertidal shellfish tenures on or near them:
    - Salmon streams
    - Eelgrass beds
    - Kelp beds
    - Herring spawn areas
    - Estuaries
    - Smelt and sand lance spawning beaches
    - Salt marshes
    - Mudflats
    - Significant fish holding and passage areas.

Recommendations for successful, low-impact beach culture:

- Explore options to culture native species such as Olympia oysters. Groups in Washington State are restoring and farming Olympia stocks.
- Leave other organisms in place when seeding product. Higher biodiversity will increase the probability of maintaining a sustainable operation and a healthy beach.
- Minimize the numbers of varnish clams on a lease via intensive harvesting or destruction.
- Do not establish beach culture sites in or near sensitive habitats. Maps of these habitats can be found for some areas of B.C. on the Community Mapping Network web page.[32]
- Suspend intensive activity during bird migration periods if you are on known migratory bird stopover, feeding or flocking location.[33]
- Raise crew awareness regarding proper disposal of materials such as pieces of rope and bags.
- Raise crew awareness of prescribed mitigation, including:
    - Netting must be a prescribed distance from eelgrass habitat
    - Spill kits must be kept on-site
    - Herring are to be allowed to spawn on in-water structures

a. Substrate disruption

- **Digging** – Natural wave and wind activity creates layers in beach sand and organisms. Digging of harvest clams disrupts the natural placement of the substrate, upsetting the natural beach layering.
- **Compaction** – Substrate is also flattened, or compacted, by human activity, especially use of vehicles.
- Mechanical harvest – Mechanical harvest methods are used in some parts of the world. DFO does not allow mechanical harvesting, although there are efforts being made to develop alternate methods of mechanical harvest.

Recommendations for minimizing substrate disruption:

- Leave substrates and beach life in place.
- Hand-dig clams.
- Replace substrate after clams are removed.
- Keep heavy equipment and vehicles off the beach.

See also:

- BCSGA CoP: pp.28 Tenure Modification
- MAFF CoP: Section 2.0. p.4 Tenure Modification

b. Anti-predator netting

Anti-predator netting is an expensive way to prevent birds and other predators from eating young shellfish. Once shellfish reach a certain size, they don't need this level of protection. The following issues should be addressed when considering use of anti-predator netting:

- **Migratory birds** – Many migratory bird species depend on flat beaches and some feed on shellfish as a natural part of their diet. Shellfish farms are often sited in areas that are prime feeding areas for migratory birds. Studies are currently underway to study migratory bird feeding patterns and to determine how they are affected by commercial shellfish operations. Shellfish operators should ask and address the following questions:
  - Will excluding birds from using natural feeding areas with anti-predator netting have a measurable impact?
  - How will changes in concentration and amount of available food alter feeding patterns or migratory routes?
  - Will a change from multiple food species to a dominant single-species source of food affect behavior, health or survival rates?
- **Human activity** – A recent study shows that human activity affects bird foraging behavior.[34] The impacts of farming operations which involve intense human activity must be acknowledged and avoided.
- **Beach dynamics**
  - Nets change beach dynamics by preventing natural movement

of substrate caused by waves and wind.

- Nets encourage algal growth, which alters beach nutrient levels.
- Nets with algal growth shade substrate, affecting the benthic community below.
- Use of anti-predator nets should be minimized or eliminated.

Recommendations for avoiding the impact of netting on birds:

- Test whether nets are actually beneficial by doing pilot plots without nets when establishing a new operation.
- If you decide that you require netting, use as little as possible.
- Leave gaps between panels of netting so that birds can locate foraging areas.
- Lift nets during summer to avoid fouling (adjust timing to local conditions). This will allow the beach to recover a more natural state and retain a healthier balance between all organisms using the beach. This in turn will encourage longer-term health of beach biodiversity.
- Avoid areas which are inappropriate for netting, including:
  - High bird use areas (migrating and feeding)
  - Sites with high nutrient levels (will get extensive biofouling) such as;
    - Areas near marine upwellings
    - Areas near human settlements where there might be sewage outflow
    - Areas near agricultural run-off

See also:

- BCSGA CoP pp. 20-23 Interaction with Wildlife Including Predator Control
- BCSGA CoP pp. 26-27 Biofouling Control
- MAFF CoP Section 8.0 p.10 Interaction with Wildlife
- MAFF CoP Section 10.0 p.12 Biofouling Control

c. Beach Barriers

Shellfish are moved across a beach by tidal action, storms and wind. Rock walls and vexar fencing are sometimes used to keep shellfish on a leaseholder's land. When oysters build up against the barriers, it is good husbandry to re-distribute them over the beach. Some farmers put frequent barriers on their beaches so that workers don't have to move oysters as far when spreading them out. However, barriers have several potential problems associated with them.

- **Beach dynamics** – The way that wind and water move the sediment on beaches and intertidal areas determines the shape of the shoreline and shore functions. Moving large substrate around to form walls disturbs the pattern of substrate movement, or deposition. While this may not seem to make a large difference in the short run, it could eventually lead to significant changes to beach shape and size. This can be seen with the changes after a small rock wall is installed.

- **Fish passage** – The beaches which make excellent shellfish farms often have streams passing over or near them. If salmon spawn in those streams, there will be small juveniles migrating out of the streams and adults returning to spawn. Many of B.C.'s fish stocks are in decline, and these fish already have to survive an obstacle course during their lives. In addition to human activity, netting, changes in nutrient composition and availability, vexar fences add yet another barrier for fish to overcome.

MAFF will not allow tenures near streams unless they use no fences or nets.

Recommendations for succeeding with minimal fencing:

- Avoid using fencing at all, even if the site allows for it.
- Build fences to follow natural contours of the beach.
- Use short staggered sections of fence.
- Work with natural substrate such as boulders found at the site.
- Do not move large intertidal substrate to create walls.
- If fencing, do not create enclosed areas (see photo)

See also:

- BCSGA CoP: pp.28-29 Tenure Modification
- BCSGA CoP: pp.36-37 Navigational Safety
- MAFF CoP: Section 2.0, p.4 Tenure Modification
- MAFF CoP: Section 14.0, p.16 Navigational Safety

photo: Heather Deal

Intensive fencing causes significant changes to an intertidal zone and may impede fish passage.

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photo: John Harper

A clam garden was cultivated along this shoreline.

Siting a shellfish farm is the most crucial element in planning a successful operation that minimizes impacts.

photo: Heather Deal

Growing oysters to maturity in bags may reduce the impact of beach grow-out operations. However, there are no studies comparing impacts of various methods of oyster grow-out.

Due diligence must be paid to the potential for ennvironmental impacts at a given site.

photo: Heather Deal

Stacks of vexar bags reduce the horizontal footprint of a farming operation on the beach surface.

Many types of habitats are considered sensitive due to their high ecological value and vulnerability to damage.

Productive capacity studies are being undertaken in several places in B.C. as the shellfish farming industry expands.

photo: Heather Deal

The beaches which make excellent fish farms often have streams passing over or near them.

The earth's biodiversity forms a foundation for the quality of human life as well as the raw materials to enrich it.

Depletion of plankton can lead to a decrease of competing plankton feeders, which are food for larger and more complex organisms.

photo: John Harper

David
Suzuki
Foundation

SOLUTIONS ARE IN OUR NATURE

David Suzuki Foundation
219 - 2211 West 4th Avenue
Vancouver, BC Canada V6K 4S2
Tel: 604-732-4228 • Fax: 604-732-0752

www.davidsuzuki.org