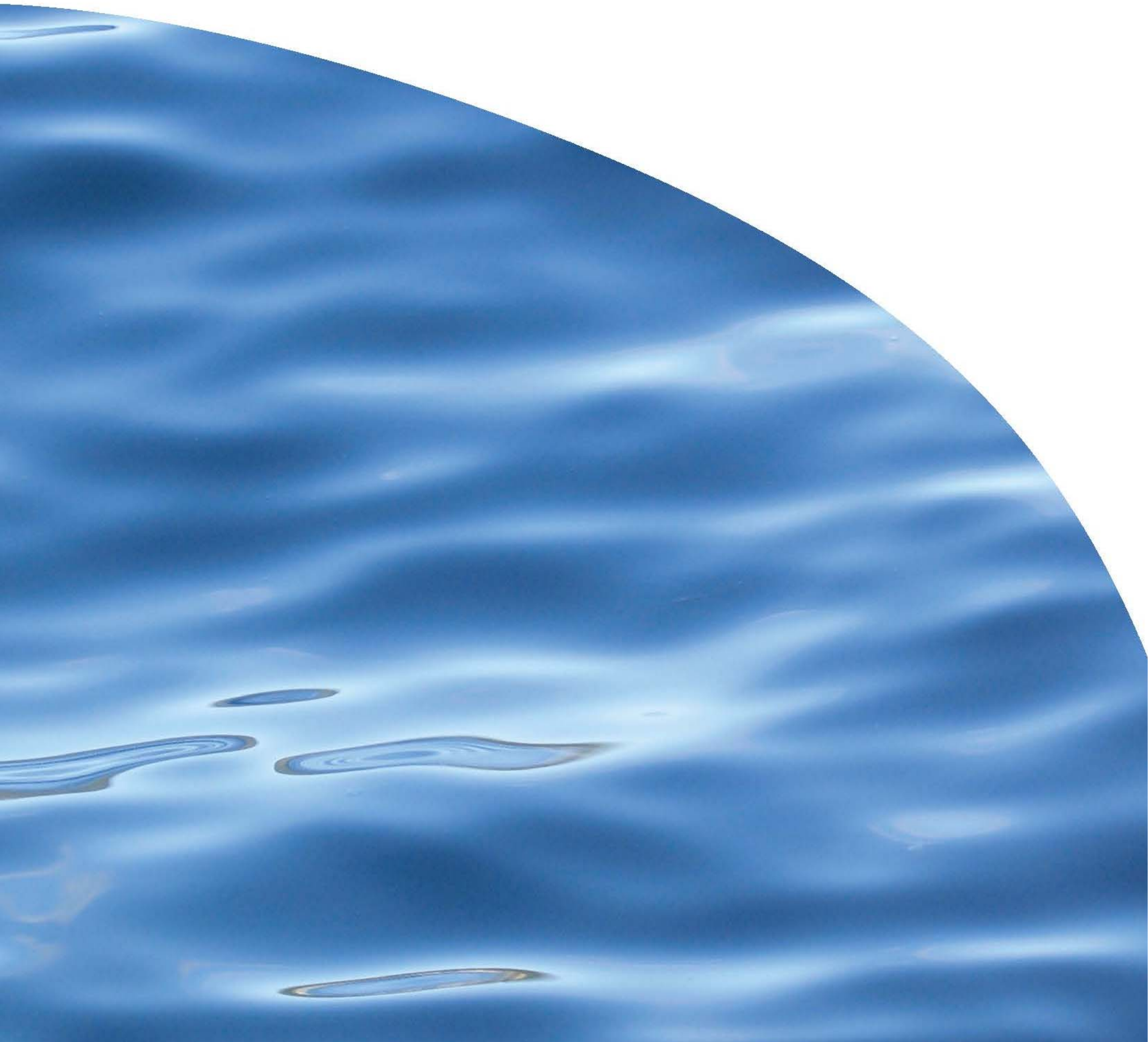
REPORT NO. 2266

RISK OF HARVEST - ASSOCIATED SPREAD OF THE INVASIVE KELP*, UNDARIA PINNATIFIDA* IN SOUTHLAND



RISK OF HARVEST - ASSOCIATED SPREAD OF THE INVASIVE KELP, *UNDARIA PINNATIFIDA* IN SOUTHLAND

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Figure 1. *Undaria pinnatifida* growing on mussel farm structures in Tory Channel, Queen Charlotte Sound. Photo credit: B Forrest.

EXECUTIVE SUMMARY

Undaria pinnatifida is a non-indigenous kelp that is classified as an 'unwanted organism' under the Biosecurity Act 1993. It has become widespread in New Zealand since its discovery in the mid-1980s. *Undaria* is considered a threat to natural ecosystems and associated values, but it is also a commercially valuable product both as a food, and because of its range of pharmaceutical properties. As such, there is interest in commercial *Undaria* harvest and aquaculture in New Zealand.

In Southland, *Undaria* is known to be well-established in Bluff and in parts of Stewart Island. No *Undaria* has been sighted in Fiordland, except for an isolated incursion in Breaksea Sound, for which a local elimination attempt is underway. Human activity is the dominant cause of spread of *Undaria* over long distances. Further spread of *Undaria* is of particular concern given the high conservation values in Southland.

Applications to harvest *Undaria* commercially are made to the Ministry for Primary Industries under the Biosecurity Act. Applicants in Southland are further required to seek exemption from rules in Environment Southland's Regional Pest Management Strategy (RPMS).

Environment Southland needs to be able to make fair and consistent decisions on applications for exemption from rules within the RPMS. The Cawthron Institute was contracted to provide scientific advice on the environmental risks associated with commercial harvest of *Undaria* and to provide guidance on risk mitigation measures that could be adopted by harvesters.

Substantial risk of spread of *Undaria* occurs in association with current human activities in Southland, but commercial *Undaria* harvesting has the potential to increase this risk. Risk is identified at four main stages of harvest-associated activity: at the harvest site, during transport and unloading of harvested material, during processing and disposal, and with subsequent use of equipment and vessels.

The two main sources of harvest-associated risk are movement of reproductive material to new sites during transport, and use of harvest associated equipment and vessels at non-infested sites subsequent to harvest activities. These risks can be mitigated to the point that they do not present a greater risk than that associated with current activity, and low risk harvest and transport scenarios are identified. Mitigation measures are summarised in Figure 2 below, and include containment of material during harvest and transport, and treatment of vessels and equipment. Ministry for Primary Industries guidance provides a range of treatments to reduce the risk of spreading *Undaria*. The appropriateness of treatment methods would depend on the risks of spread in environments on the transport route, and where subsequent use of vessels and equipment may occur.

	SOURCES OF RISK		MITIGATION MEASURES
Harvest site	Local increase in density or spread from: • Drift plants • Disturbance (increasing invasiveness)	⟹	• Hand-harvest and secure containment • Removal of plants at base of sporophyll
Transport and unloading	Regional spread if reproductive material is released into non-heavily infested areas: • En route • At port	⟹	• Store plants in non-draining containers • Secure containers to avoid loss • Reduce contamination risk by treating vessel prior to leaving harvest site • Consider appropriateness of unloading site • Careful off-loading
Processing	Accidental release or return of material to coastal areas	⟹	• Dispose of waste plant material and runoff on land where it cannot be inadvertently re-introduced into the marine environment
Subsequent use of vessel and equipment	Contamination of any vessels and equipment associated with: • Harvest • Transport and unloading • Processing	⟹	• Consider risk of spread in environments where vessels and equipment will be used after harvest activities, and treat accordingly

Figure 2. Source of risk and mitigation for *Undaria pinnatifida (Undaria).*

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1. INTRODUCTION

Undaria pinnatifida is a non-indigenous kelp that is classified as an 'unwanted organism' under the Biosecurity Act 1993. It has become widespread in New Zealand since its discovery in the mid-1980s (Hunt *et al.* 2009). *Undaria* is considered a threat to natural ecosystems and associated values (*e.g.* http://www.biosecurity.govt.nz/pests/undaria), but it is also a commercially valuable product both as a food, and because of its range of pharmaceutical properties. As such, there is interest in commercial *Undaria* harvest and aquaculture in New Zealand.

In Southland, *Undaria* is known to be well-established in Bluff and in parts of Stewart Island (Big Glory Bay and Half Moon Bay). Some spread has occurred from these areas, but distribution has not been recently described. No *Undaria* has been sighted in Fiordland, except for an isolated incursion of *Undaria* in Breaksea Sound, for which a local elimination attempt is being managed under a joint agency agreement between Environment Southland (ES), Ministry for Primary Industries (MPI) and the Department of Conservation (DOC). These agencies are also working on regional pathway management in order to reduce the further risk of *Undaria* and other invasive organisms being transported into Fiordland.

There is currently interest in commercially harvesting *Undaria* in Southland. Applications to harvest *Undaria* are made to MPI under the Biosecurity Act. Ministry for Primary Industries requires applicants to give consideration to high value areas in the vicinity of proposed harvest locations, and outline ways in which environmental risks from harvesting and associated activities will be minimised. MPI do not currently allow *Undaria* farming in Southland, and harvest from natural substrates can only be considered as part of a control programme, or as by-catch from another activity.

In addition to the MPI application process, applicants in Southland will be required to seek exemption from rules in ES's Regional Pest Management Strategy (RPMS). The RPMS designates *Undaria* as a 'containment pest', and objectives include:

- To prevent the human spread of *Undaria* within the Southland region.
- To support programmes aimed at reducing the distribution and density of *Undaria* where it has established in the region during the term of the Strategy.

Environment Southland needs to be able to make fair and consistent decisions on applications for exemption from rules within the RPMS. Such decisions largely hinge on whether commercial harvest proposals could give rise to unacceptable risks, relative to the status quo. Therefore, ES contracted the Cawthron Institute (Cawthron) to provide scientific advice on the environmental risks associated with commercial harvest of *Undaria* and to provide guidance on risk mitigation measures that could be adopted by harvesters.

Although commercial harvest and aquaculture are currently limited by MPI policy, we have provided an overview of additional considerations to provide ES with decision-making support in the event of any changes in policy. The report is therefore structured such that currently permissible harvest scenarios are considered first. We note that many of the same risks arise in relation to aquaculture and harvest from natural habitats, and the mitigation methods are similar. Additional risks presented by currently non-permissible activities are discussed at the end of this report (Section 5).

2. BACKGROUND TO *UNDARIA* MANAGEMENT AND RELATED BIOLOGY

An understanding of the importance of the *Undaria* issue in Southland, and the environmental risks from harvest or culture, require a summary of the key biological attributes of *Undaria* that affect its invasiveness and spread.

2.1. *Undaria* distribution in Southland

Undaria has successfully established and spread throughout New Zealand, reaching high densities in numerous coastal areas. In Southland, *Undaria* was first found in Big Glory Bay in 1997. An elimination attempt was initiated in 1998, and extended to Bluff in 1999, and Halfmoon Bay in 2000. However, after the discovery of a new population in Halfmoon Bay the programme was discontinued from 2004. Although areas of both Bluff and Stewart Island are now heavily infested[1], there is still considerable interest and concern regarding the spread and impacts of *Undaria* in Southland, given the region's very high conservation values. Accordingly, efforts to eliminate the kelp from Breaksea Sound are underway, as is an evaluation of the scope for managing risk pathways, especially from Bluff Harbour (Sinner *et al.* 2009).

2.2. *Undaria* natural history

Undaria is an annual species, and its life cycle includes microscopic life stages as well as the large sporophyte (*i.e.* seaweed) stage (Figure 3). The seaweed stage of *Undaria* is fast-growing (up to 2 cm/day) and individuals are relatively short-lived (~5–9 months). In Southland, *Undaria* is visibly present for most of the year (Hunt *et al.* 2009).

The frilly structure (termed 'sporophyll'), which develops at the base of the seaweed, produces spores (the first of the microscopic life stages) when mature. Over time the blade of the seaweed degrades, but the sporophyll remains and can continue to produce spores for several weeks to months. Millions of spores are released, swim for a short period, then settle onto the seabed or other hard surfaces. The spores then develop into the microscopic gametophytes which produce sperm and eggs; a single seaweed will produce both male and female gametophytes. Fertilized eggs then develop into the next generation of seaweed.

[1] MPI define 'heavily infested' as areas where "Undaria is present and conspicuous over an 'extended spatial area' and where Undaria has been present for greater than five years. The term 'extended spatial area' is considered to be those situations where Undaria is present on the shoreline or on marine farms on a 1 km or larger scale, including areas where Undaria is spatially or temporally patchy throughout the year." (http://www.biosecurity.govt.nz/files/biosec/policy-laws/implementation-undaria-farming-information-paper.pdf).

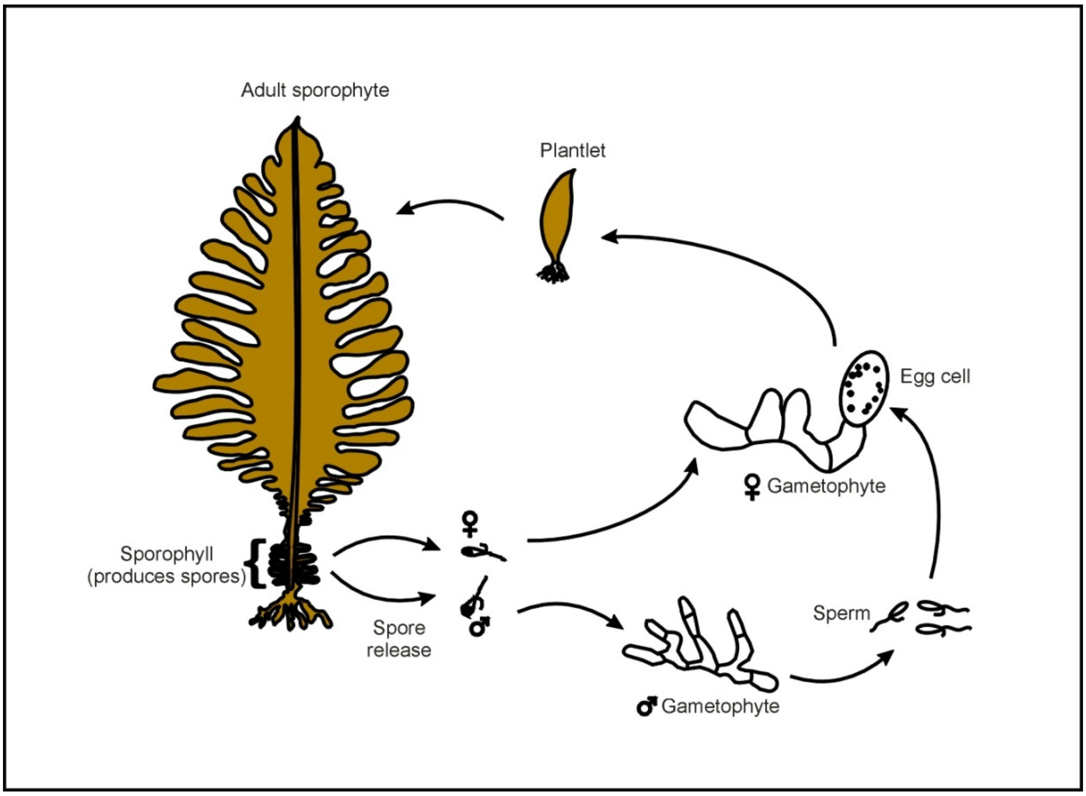

Figure 3. Life cycle of *Undaria pinnatifida* showing visible (brown) and microscopic (no shade) phases (from Forrest 2007).

As for any organism, *Undaria* has environmental limitations, and some regions will be more suitable for growth than others. Conditions in Southland are particularly suitable for both the growth and the spread of *Undaria*. It can tolerate a wide range of water temperatures, but requires cool waters for reproduction (Thornber *et al.* 2004). The suitability of Southland's waters for growth of *Undaria* was demonstrated when mussel lines from an area of the Marlborough Sounds, with no visible *Undaria* (i.e. microscopic gametophytes were present), produced abundant plants three weeks after being moved to Big Glory Bay (Hunt *et al.* 2009).

Undaria requires hard substrata for growth of the seaweed life-stage. It can be abundant on rocky reefs from the intertidal to *c.* 22 m depth where water clarity is high. It also grows particularly well on artificial structures (Hay 1990; Thornber *et al.* 2004). *Undaria* has also been found on debris such as discarded bottles and tyres, small rocks and gravel (Hay & Luckens 1987), and even on the shells of mobile animals such as hermit crabs and paua. In a study of spread along the south-eastern coast of the South Island, it was concluded that all coastal habitats should be considered suitable for the growth of *Undaria* (Russell *et al.* 2008). Disturbance can encourage *Undaria* to grow more densely, as both removal of the seaweed canopy and disturbance of the reef surface can promote growth (Valentine & Johnson 2003; Thompson 2004).

Undaria is thought to be able to survive in the microscopic life stages for several years (Hewitt *et al.* 2005). Accordingly, when conditions such as light, water-temperature, wave-exposure are suitable for growth this 'seed bank' can produce abundant seaweed growth.

2.3. Dispersal mechanisms and spread of *Undaria*

Undaria has a relatively limited capacity for dispersal by natural mechanisms, and human activity (*e.g.* movement of infested vessel hulls or aquaculture equipment) is the dominant cause of spread over large distances. Following human-mediated introduction, natural dispersal is very important for the local spread and development of *Undaria* populations. Short-distance natural dispersal has the potential to greatly extend *Undaria*'s range over periods of years or decades where continuous suitable habitat exists. Accordingly, human-mediated spread becomes most important when it moves species, such as *Undaria,* beyond barriers to their natural dispersal (Forrest *et al.* 2009).

Spread from natural dispersal occurs via spore release from reproductively mature attached or drift plants. *Undaria* spores may survive at least 14 days under laboratory conditions (Forrest *et al.* 2000). Spores that are caught up in water currents or otherwise transported away from the adult plant could therefore be transported long distances. However, it is generally the case that spores need to settle and develop to the gametophyte stage very close to a gametophyte of the opposite sex for fertilization of eggs to occur. This means that the dilution of spores will reduce the chance of successful establishment. As such, even though millions of spores may be released from an *Undaria* plant or population, spread is generally limited to quite small distances (tens to a few hundred metres) from the release point. The possibility of spores clumping together (Forrest *et al.* 2000), asexual reproduction (Fang *et al.* 1982; Ranelletti 2006), and hybridisation with other kelp species (Ranelletti 2006) are recognised, but the implications for population spread are unknown.

Local scale spread can be greatly exacerbated by the drift of plants that continue to release spores (Forrest *et al.* 2000). Plants may be detached by natural processes (*e.g.* storms) or anthropogenic activities (*e.g.* defouling of aquaculture structures). Drift plants are considered to play a key role in the spread of *Undaria* along the coast of the South Island (Russell *et al.* 2008). Because one mature plant can produce numerous offspring, a single plant washing up in a suitable new location may cause a new population to establish. Another relevant mechanism was described in Tasmania, where the drag created by plants growing on shallow subtidal cobbles lead to cobble dislodgement and long shore drift (Sliwa *et al.* 2006). *Undaria* spread over scales of several kilometres have been described as a result of drift processes, and chance events could result in occasional movements of much larger distances (Reed *et al.*

1988). The stormy conditions in Southland are likely to assist in dispersal of both spores and drift plants.

3. *UNDARIA* COMMERCIAL HARVEST SCENARIOS AND SOURCES OF RISK

In this section we consider only scenarios relevant to currently permissible harvest. In the absence of knowledge of the details of harvest proposals and intentions, we have assumed that both the blade and the sporophyll would be targeted in harvest operations. We also expect that harvesters would target only areas that are heavily infested, as it would be uneconomic to target low density *Undaria* populations.

3.1. Harvest products and techniques

Harvest would generally target plants at the age where the blade is well-developed (at which point they are already reproductively mature), but has not begun to degrade. The edible blade is used for *wakame* (*e.g.* in miso soup) whereas the sporophyll can be used to make another edible product called *mekabu*. The most likely harvest method in Southland is divers cutting off the plant below the sporophyll, or surface harvesting from raised mussel lines or other structures (*e.g.* vessel mooring lines). However, a range of harvest techniques for *Undaria* in particular, and seaweeds in general, are employed around the world, and may include mechanical methods (see Appendix 2 for a summary of *Undaria* harvest methods). Post-harvest, we assume that *Undaria* would be transferred to a boat (on the basis that a boat would usually be needed to access mid-water structures), and then transported to a processing location on shore.

3.2. Sources of risk at harvest site

3.2.1. Overview

Key components of the risk of harvest-related spread are:

- Increases in density or spread of *Undaria* at the harvest site resulting from:
    - Spore dispersal from drift plants.
    - Disturbance during harvest.
- Regional-scale spread of *Undaria* resulting from the movement of harvested product, vessels and equipment away from the site. Risks are likely to be present at three main stages:

- o The transport of the *Undaria* between the harvest and processing sites.
- o *Undaria* processing and disposal of waste matter.
- o The subsequent transport and use of equipment and vessels (which are likely contaminated by *Undaria*).

The highest risk of harvest-associated spread probably occurs when the harvested product, or equipment used during harvest, is transported away from the harvest site (see below).

3.2.2. Increases in density or spread at the harvest site

Drift plants could be produced during harvesting or the transfer of *Undaria* to vessels for transport. However, the production of drift plants is likely to be less than the status quo. Drift-plant production from defouling activities, especially on mussel farms, is probably high at present, as *Undaria* and other biofouling are removed as part of routine operations. For example, mussel farm floats and double backbone lines may be defouled manually from time to time, and crop long-lines are mechanically defouled during harvest operations. It is not regarded as feasible for such material to be captured, meaning that it will usually drift away and eventually fall to the seabed. Harvest of *Undaria* therefore has the potential to reduce the production of drift plants substantially, especially when precise methods are used, such as removal of individual plants by divers, or manual removal from mussel-lines at the surface. Non-targeted harvest methods such as the use of machinery or long-handled blades to cut submerged plants from the surface (non-diver collected) could result in a greater amount of drift material than targeted collection, but again it would probably be less than that currently produced by routine defouling. Overall, harvesting activities at the collection site are unlikely to increase the risk of spread by drift plants from the status quo; in fact the amount of drift could decrease.

Spore supply at the harvest site may be reduced from the status quo since the plants that are most commercially valuable (no blade degradation) have not yet released all their spores. Removing plants could accordingly reduce short-term spore supply at the harvest site, but this will only have the potential to limit *Undaria* densities in the medium to long-term if harvest is intensive and on-going. In the short-term, by making more space available, harvest may promote the growth of the next generation from the ‘seed bank’ of microscopic plants which have already settled nearby. This could increase spore supply near vessels, increasing risk of transport of *Undaria* via vessel fouling. It is most likely, however, that in these environments spore supply is likely to already be so high that changes following disturbance will have limited impact.

Some artificial structures support fouling communities which are highly valued. Extreme examples of this would include shipwrecks and artificial reefs, but other structures that are not regularly defouled may also support communities of value.

High harvest-associated disturbance could be considered unacceptable for such communities.

Commercial beach harvest (of any seaweed species) in Southland is currently restricted to the area between Waimatuku Stream (east of Riverton) and Waiau River, Te Waewae Bay, and the area between Ackers Point and Lee Bay on Stewart Island (http://www.legislation.govt.nz/regulation/public/2002/0015/latest/DLM109382.html). Harvest of beach-cast *Undaria* may stop it returning to the sea as drift, and limit localised spore supply, but since only a small proportion of total drift washes up as beach-cast, it is unlikely to have a measurable effect on plant spread or density.

3.3. Risk of harvest-associated regional spread

Any introduction of reproductive material of an unwanted organism to a new environment carries some degree of risk, and current activities and vessel traffic in Southland present a substantial risk of spreading *Undaria*. For example, a high proportion of vessels in the region have been found to be fouled with *Undaria* (~30–40 %, Stuart 2000, Sinner *et al.* 2009), and equipment and materials associated with aquaculture and fishing (*e.g.* rock lobster pots and harvested mussels) are moved from heavily infested areas into or through areas not known to have *Undaria* populations.

Even when a certain level of invasion risk is present, however, the implications of increasing invasion pressure should be considered. An increase in the amount and/or frequency of supply of reproductive material to a new environment can represent an important increase in the chance that individuals will settle in the densities and conditions they require for successful and rapid establishment (Hayden *et al.* 2009; Simberloff 2009).

Harvest-associated risk factors are similar to the risk factors associated with existing activities. These include contamination of vessels or equipment via spores entrained in water (*e.g.* bilge water), by settlement of gametophytes (*e.g.* on equipment or vessel hulls), or by the transport of whole plants or fragments of reproductive tissue. For example, when *Undaria* is hauled onto the deck of a boat fragments and spores can accumulate in reservoirs and deck spaces. Incidental spread by human activity is likely as spores may be viable for some time in water (see Section 2.3), and *Undaria* gametophytes or fragments may survive air exposure for hours to days, (especially in humid conditions, Forrest & Blakemore 2006).

3.3.1. Transport and unloading of harvested material

The large amounts of material transported under a commercial *Undaria* harvest scenario present a particularly high risk of increasing spread. Storage and transport may provide the perfect conditions for spore release from mature *Undaria*. Water which has been in contact with stored plants may contain very high densities of spores, and should be considered a high-risk material if released outside of infested areas. Drift plants could similarly be high risk if not stored securely during transport.

Unloading at any site that is not infested with *Undaria* would present substantial risk as any associated reproductive material that escaped from the harvested product, the transport vessel or other equipment, may be released into a highly suitable environment for *Undaria* growth (*i.e.* shallow waters, proximity to artificial structures). Bluff Harbour is a highly infested area, and unloading and rinsing of vessels and equipment there is unlikely to increase risk of spread of *Undaria*.

3.3.2. Processing and disposal

Once on land, it is important that no *Undaria* be returned to the sea. As noted above, some reproductive material can survive relatively long periods of air exposure and also immersion in freshwater (48 hours in 10 °C is required to ensure no viable material remains). This means *Undaria* material released into streams or stormwater, could remain viable until it reaches the sea. .

3.3.3. Subsequent use of equipment and vessels

Equipment and vessels used in any part of the harvest, transport and processing operations, and then taken outside of infested areas, may release reproductive material and increase spread. Dive equipment, gloves and other clothing, equipment and surfaces used during harvest or processing, and the vessel used for transport can all function to transport *Undaria* to new areas. Vessel reservoirs such as the bilge which could retain spore-laden seawater would be of particular concern (Darbyson *et al.* 2009). Similarly, any sporophyll fragments (*e.g.* on the deck of the vessel) could pose a risk if washed back into the water at a new location.

4. BEST MANAGEMENT PRACTICES

In this section (as in Section 3) we consider only scenarios relevant to currently permissible commercial harvest.

The most important factor in limiting harvest-associated spread of *Undaria* is containment during transport, unloading and processing, and treatment of equipment and vessels associated with any part of the harvest operation before subsequent use outside of areas heavily infested with *Undaria*.

A summary of risk and mitigation measures is presented below (Figure 4).

	SOURCES OF RISK		MITIGATION MEASURES
Harvest site	Local increase in density or spread from: • Drift plants • Disturbance (increasing invasiveness)	⟹	• Hand-harvest and secure containment • Removal of plants at base of sporophyll
Transport and unloading	Regional spread if reproductive material is released into non-heavily infested areas: • En route • At port	⟹	• Store plants in non-draining containers • Secure containers to avoid loss • Reduce contamination risk by treating vessel prior to leaving harvest site • Consider appropriateness of unloading site • Careful off-loading
Processing	Accidental release or return of material to coastal areas	⟹	• Dispose of waste plant material and runoff on land where it cannot be inadvertently re-introduced into the marine environment
Subsequent use of vessel and equipment	Contamination of any vessels and equipment associated with: • Harvest • Transport and unloading • Processing	⟹	• Consider risk of spread in environments where vessels and equipment will be used after harvest activities, and treat accordingly

Figure 4. Sources of risk and mitigation measures relevant to the commercial harvest of *Undaria*.

It is important to note that despite the adoption of best management practices, residual risks may remain. For example, reproductive material may due to equipment failure or accident, even when reasonable care has been taken to contain such material. Therefore best management is primarily about risk reduction rather than the complete elimination of risk.

4.1. Harvesting procedures

The following harvest methods can be used to minimise the potential for *Undaria* spread:

- **Hand-harvest and secure containment of individual plants:** Drift plant production from the harvest site can be kept (or reduced) to very low levels with this method and should be straightforward for structures that are lifted from the water. Diver collection of individual plants in the subtidal allows for containment in catch bags or similar, so escape of drift plants would be minimal.
- **Harvest methods that limit disturbance of the substratum:** Collecting individual *Undaria* plants by cutting at the base of the sporophyll and leaving the holdfast undisturbed will limit disturbance and therefore potential for spread.

Any harvest of beach-cast *Undaria* should avoid sensitive areas; this is currently required by beach harvest regulations.

4.2. Transport and unloading procedures

Transport of *Undaria* outside heavily infested areas requires measures to ensure risk of spread is reduced to no more than that associated with current activities in Southland. If the harvested product is being taken to non-heavily infested areas for unloading it is especially important that stringent treatments are in place. It may be that no scenario is considered sufficiently low risk in un-infested areas, and an alternate unloading point would be required.

The following management measures for transportation may be used to avoid the discharge of *Undaria*-contaminated water or viable fragments and the risk of spore spread:

- Store harvested material in non-draining containers or compartments during transport outside of harvest areas.
- Transport harvested plants in well-secured containers.
- Prior to leaving the harvest site, the following should be undertaken:
    - Hose down vessel deck spaces and equipment to remove any visible *Undaria* fragments, and ensure the water drains from the boat before departure.
    - Discharge or flush out any bilge water, or other retained water, that is potentially contaminated with *Undaria*.
    - If harvested plants are being transported to an un-infested area, use more stringent cleaning treatments such as environmentally-friendly chemical sprays or immersion treatments (see Appendix 1).

- Containment and careful treatment of materials and equipment when unloading in un-infested or non-heavily infested areas.
- Assess post-transport contamination risk and treat accordingly. For example, assess whether holding compartments on the vessel retain material, or whether other parts of the vessel have been re-contaminated.

4.3. Processing and disposal

Once on land, no viable reproductive material should be re-introduced into waterways (*e.g.* storm-water, streams) which could transport material to coastal areas which are not heavily infested. Rather, material should be disposed of on land where it cannot be inadvertently re-introduced to the marine environment.

Untreated rinsing water and run-off from equipment such as storage containers should not be released into stormwater or any other waterway connected with coastal areas which are not heavily infested. Equipment and run-off should either be treated with environmentally-friendly chemicals, or poured onto land (where it will not inadvertently reach any waterway).

4.4. Subsequent use and treatment of harvest equipment and vessels

4.4.1. General considerations

A high risk of regional spread exists where vessels or equipment involved in harvest or transport of *Undaria* is subsequently used in areas that are not heavily infested. Vessels or equipment specifically used for *Undaria* harvest and transport have a higher likelihood of contamination than those involved in other activities. This risk can be mitigated with the basic cleaning, transport and unloading procedures described in Section 4.2.

Some scenarios of post-harvest equipment and vessel use may warrant additional or more stringent cleaning procedures. One such scenario is where commercial divers, who may be employed to harvest *Undaria*, would go on to dive in un-infested areas in the days or weeks following. Viable *Undaria* could be present on diving equipment, therefore it should be cleaned appropriately between locations (see Box 1 and Appendix 1). Another likely scenario is that a harvest vessel unloads in Bluff Harbour and then moves to an un-infested area. In that instance, it would be expected that the same cleaning protocols (*i.e.* cleaning of deck spaces and equipment and bilge discharge) would be applied as a precaution prior to departure. This approach would be necessary if run-off was contained in vessel compartments during transport, rather than in separate sealed containers. In a port such as Bluff, it may also be possible to make cleaning more effective by rinsing or washing decks and gear thoroughly with freshwater; preferably soaking gear in fresh (hot) water and thoroughly air-drying (Box 1).

To reduce the spread of *Undaria* by vessels leaving Bluff Harbour (or other infested areas) for un-infested areas, it could be argued that more severe defouling and cleaning procedures would be appropriate (*e.g.* using chemical cleaners as described below). The Ministry of Primary Industries (MPI) have been developing a specific package of management measures that aim to minimise the human-mediated introduction of *Undaria* and other marine pests (*e.g.* Sinner *et al.* 2009). A range of issues need to be addressed before widespread use of chemical treatments is considered and these are outlined in Section 4.4.2.

Box 1. Simple treatments for equipment that may be contaminated with *Undaria*.

(Clean Boats - Living Seas, boaties guide for marine biosecurity can be downloaded at http://www.biosecurity.govt.nz/biosec/camp-acts/marine/cleaning)

1. Rinse all surfaces, ideally with freshwater
2. Immerse gear in ample freshwater at least overnight, and for 48 hours if possible. The volume of freshwater must be more than 100 times that of any residual salt water on the equipment to ensure salinity does not rise to the point that it allows for survival of reproductive material. Ideally water would be replaced at least once to ensure low salinity.
3. The effectiveness of freshwater can be enhanced by using warm or hot water. Hot water at typical tap water temperatures (55-65 $^{\circ}$C) would be effective in a matter of minutes.
4. Preferably air-dry gear after soaking in freshwater. Air-drying alone make take several days to be effective, and possibly several weeks in humid conditions. Hence, expose drying gear to a good air flow where possible.
5. Dive gear should ideally be rinsed with a wetsuit cleaning product, or treated as per recommendations in Appendix 1.

4.4.2. Additional treatments

Although a range of relatively simple treatments to reduce risk are possible there is no widely accepted guidance on the best or most appropriate treatments. See Appendix 1 for specific recommendation from MPI on treating boats and equipment for marine pests. A number of issues that may reflect on the effectiveness or utility of the guidance include:

- Most of the available guidance is based on experimental studies, and has seldom been routinely applied at an operational scale for biosecurity purposes.

Hence, both the practicality and broad efficacy of the methods remains untested. It is unlikely that any method could be practically applied in such a way that it completely negated risk; risk reduction is a more realistic goal.

- Effectiveness of any chemical treatment will depend on the method of application (*e.g.* spray vs. immersion) and the combination of chemical concentration and contact time. Increasing the chemical concentration can reduce the contact time required, but potentially cause occupational safety and health or environmental issues.
- There may be some unintended adverse effects of some chemical treatments effective against marine pests. For example, while detergents may be effective against the spread of marine pests, guidance provided to boaters as part of the clean boating programme[2] suggests that detergent should never be mixed with oily bilge water as the mixture can be even more toxic than oil alone.
- Requirements for permitting and disposal would need to be considered for some chemical treatments. This is likely to require an appraisal of ES and central government (through the Environmental Protection Authority) requirements. An evaluation of such needs is beyond the scope of this report.

[2] http://www.cleanboating.org.nz/data/Bilge%20Water%20v2.pdf

5. FURTHER CONSIDERATIONS

5.1. Harvest from natural reefs

Harvest from natural surfaces, which would principally mean intertidal or subtidal rocky reefs, is currently not permitted except as part of a control programme or by-catch of another activity. No control programmes are currently operating in Southland, except for the eradication attempt in Breaksea Sound where very few large plants have been found.

If *Undaria* is regularly and intensively harvested from natural reefs, coverage can be substantially reduced, although 'hotspots' of new plant growth will remain (Hewitt *et al.* 2005). Harvesters are presumably going to target large plants that have reached maturity (and therefore have likely released some spores). This, along with the longevity of the microscopic stages of the *Undaria* life cycle and high reproductive potential of individual plants, means that harvest will never eradicate *Undaria*. Even if intensive harvest reduces density for a period of time, strong recovery after the cessation of harvest is highly probable.

Minimising disturbance to natural communities would be of prime importance if harvesting occurs from natural habitats. Harvest-related disturbance can be caused in two main ways: by damaging the seabed community by detaching or damaging organisms, and by cutting non-target seaweeds (and other organisms) (Appendix 2). The specific ways in which disturbance affects *Undaria* growth is likely to vary depending on the characteristics of the site under consideration, and therefore it is not possible to predict the effects of disturbance in every case. Nonetheless, disturbance can encourage growth of *Undaria* and should therefore be considered a risk for increasing the density of growth where a spore supply exists. It would be expected that the only suitably low-risk method for harvesting from natural reefs is that of diver harvest by cutting between the sporophyll and the holdfast.

Shore-based harvest of attached *Undaria* is likely to cause disturbance via trampling by harvesters, and placement of equipment in the intertidal region of the shore. If shore-based harvest was permitted, sensitive habitats and areas of high ecological value areas should be avoided.

On natural reefs, *Undaria* often grows alongside other seaweeds. Grazing animals (such as paua and kina) consume *Undaria*, and may graze it preferentially over other available seaweeds (Muncaster 2002). If large quantities of *Undaria* are removed from a reef over a very short time period, grazers are likely to switch to feeding on other seaweeds. Harvest could thus create an indirect disturbance in the form of over-grazing of native seaweeds by displaced grazers. The likelihood of this occurring would depend on the density and type of grazers, the degree to which they feed on *Undaria* in preference to other available seaweeds, and the relative availability of different seaweed types. Accordingly, it is not possible to make a general prediction about the impact of such a diet switch. Research undertaken before harvesting or as part of an associated monitoring program may be required to understand such community interactions.

If harvest was considered in lightly-to-moderately infested areas, it would be appropriate to consider the danger of wider spread caused by spore release from the harvest platform (most likely to be a boat). Spore release from high in the water column is likely to lead to wider spread of spores than release from an undisturbed plant on the sea bed (Forrest *et al.* 2000). This would be of particular concern in areas where strong currents are present.

5.2. Aquaculture of *Undaria*

MPI allows applications for the aquaculture of *Undaria* in certain 'heavily infested' areas (parts of Marlborough Sounds and Lyttelton and Wellington harbours), however farming of *Undaria* is currently not permitted in Southland because of the special values in the area.

> "Farming could undermine *Undaria* and pathway management initiatives in Fiordland; could undermine the significant values of the Stewart Island, where these values in the marine environment have been acknowledged through the presence of both a mataitai reserve and a marine reserve in the area. In addition, there are significant economic values (*e.g.* tourism) associated with the perception of Stewart Island as a pristine environment. Farming a pest species such as *Undaria* may undermine Stewart Island's image as a pristine environment; and measures administered by Environment Southland may limit opportunities to farm *Undaria* within the area.
>
> Moreover, farming *Undaria* in Bluff and Stewart Island may create the perception that *Undaria* is no longer a problem in the area. A current joint agency response to *Undaria* in Fiordland and on-going pathway management for the Fiordland Marine Area relies heavily on users in Bluff and Stewart Island taking personal responsibility and managing the risks associated with any vessels or equipment they move into Fiordland. As Bluff and Stewart Island are significant donor areas for Fiordland any change in attitude of these users could impact on the long-term success of the *Undaria* programme in Fiordland" (J. Brunton, MPI).

There is no apparent way in which risk of increased *Undaria* abundance on a local scale can be limited should farming be undertaken. While the plants would most likely be harvested before they reach full reproductive output, the high densities essential to an economic farming venture would nonetheless result in extremely high quantities of reproductive material in the form of both spores and drift material being released into the local environment.

Increased supply of reproductive materials can overcome the ability of a community to resist invasion (Forrest *et al.* in press). The density of plants under farming conditions is far greater than that which occurs on natural reefs (Gibbs & Forrest 1999), and the release of reproductive material high in the water column is also likely to encourage spread. The MPI definition of a 'heavily infested area' could reasonably include large areas that do not have high cover of *Undaria*, therefore increased invasion pressure could still have a substantial effect on local abundance.

Transport, processing, and subsequent use of equipment and vessels would present the same issues as for harvest of non-farmed *Undaria* (see Section 3), except that the quantity of material transported is likely to be much higher than for non-farmed harvest.

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7. APPENDICES

Appendix 1. Further cleaning guidance from Ministry of Primary Industries (MPI)[3].

Cleaning guidance

SOAK	SPRAY/WASH	DRY
Soak the item/s as per one of the methods below: • Freshwater for at least 72 hours. If soaking ropes, freshwater should be replaced after 12 hours.[1,2,3,4] • Hot water (> 40°C) for 20 minutes.[3,5] Temperatures exceeding 48°C should not be used on dive equipment as certain temperature-sensitive gear may be damaged . • 5 percent Palmolive dishwashing detergent/ freshwater solution for 60 minutes. (5 percent solution = 500 mls of detergent into 10 litres of freshwater).[5] • 1 percent Dettol antiseptic/freshwater solution for 60 minutes. (1 percent solution = 100 mls of dettol into 10 litres of freshwater).[5] • 2 percent bleach/freshwater solution for 30 minutes* (2 percent solution = 200 mls of bleach into 10 litres of freshwater).[1,4] • 2 percent Decon 90™/freshwater solution for 30 minutes.[1,4] • 5 percent acetic acid/ freshwater solution OR undiluted household vinegar for 10 minutes* (5 percent solution = 500 mls of acetic acid into 10 litres of freshwater).[1,2] Palmolive dishwashing detergent, Dettol, bleach and vinegar can be readily purchased from most supermarkets and service stations. * Not recommended for dive gear as it may compromise the integrity of some plastics.[6]	For items too large or difficult to soak, spray the item/s as per one of the methods below: • 1 percent Dettol antiseptic/ freshwater solution and leave for 60 minutes.[5] • 5 percent acetic acid/ freshwater solution OR undiluted household vinegar and leave for 10 minutes. When spraying an item, ensure you generously cover all surfaces. Handheld sprayers can be readily purchased at a hardware store, or in the gardening department of supermarkets and other department stores.	For an item where chemical/ freshwater treatment is not feasible, remove from water and thoroughly air dry for one month.[1,2,3,4] Care is needed to ensure that the item is laid out in a manner that ensures all surfaces are completely dried. Prolonged air exposure is also an ideal complementary treatment for any item/s that has been soaked or sprayed.

Sources of information

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FOR MORE INFORMATION VISIT: WWW.BIOSECURITY.GOVT.NZ

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3 Marine biosecurity treatment guidance provided by MPI in the document "Protect Fiordland's exceptional marine biodiversity and valuable marine resources": full document including safety considerations is available at http://www.biosecurity.govt.nz/files/pests/surv-mgmt/protect-fiordland-marine-biodiversity.pdf. Information specific to boats is available in the document "Clean boats living seas" at http://www.biosecurity.govt.nz/files/enter/ships/clean-boats-brochure.pdf

Appendix 2. *Undaria* harvest methods.

Harvest methods vary in the ways they may increase the risk of spread of *Undaria*. Harvest-related disturbance can be caused in two main ways; by damaging the seabed community by detaching or damaging organisms, and cutting non-target seaweeds (and other organisms). Additionally, some harvest methods may increase the production of drift *Undaria* if plants are detached but not collected. The potential of these impacts occurring under various harvest methods is identified below.

Table A2.1. Disturbance to seabed communities and production of drift plants associated with various harvest techniques.

	Mitigation of damage to:		
Harvesting method[1]	**Seabed communities**	**Non-target canopy seaweeds**	**Mitigation of *Undaria* drift**
Attached plants			
Diver harvest (cutting)	Possible	Possible	Possible
Diver harvest (plucking, hooking)	Unavoidable (due to holdfast removal)	Possible	Possible
Surface platform harvest (cutting)	Moderate	Difficult	Difficult
Surface platform harvest (plucking, hooking)	Unavoidable (due to holdfast removal)	Difficult	Difficult
Shore-based (cutting)	Difficult due to trampling[2]	Easy if inter-tidal, but difficult if sub-tidal	Easy if inter-tidal, but difficult if sub-tidal
Shore-based (plucking, hooking)	Unavoidable due to holdfast removal & trampling[2]	Easy if inter-tidal, but difficult if sub-tidal	Possible
Mechanical harvest	Unavoidable due to holdfast removal & equipment damage	Difficult	Difficult
Hand-harvest from raised mussel lines	n/a	n/a	Possible
Drift plants[3]			
Netting from subtidal (by machine/person)	Unavoidable due to trampling[2] & equipment damage	n/a	n/a
Hand-collecting	Unavoidable due to trampling[2]	Possible	n/a

[1] Harvesting methods taken from http://www.fao.org/docrep/006/y4765e/y4765e00.htm, www.netalgae.eu/uploadedfiles/NETALGAE_WP1-2(bis).pdf, and Cheney & Mumford (1986).
[2] Trampling effects are likely to be minor since it is unlikely that harvest would occur frequently at any given site.
[3] It is more likely that dense accumulations of drift plants would occur more frequently on sandy rather than hard substrates, thus disturbance to soft habitats are likely to be minor.