Preventing the Spread of the Invasive Alga *Undaria pinnatifida* in the Santa Barbara Channel Region: Management Options and Case Studies

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Wakame (*Undaria pinnatifida*)

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Preface

The purpose of this document, "Preventing the Spread of the Invasive Alga *Undaria pinnatifida* in the Santa Barbara Channel Region: Management Options and Case Studies," is to provide the Channel Island National Marine Sanctuary Advisory Council (SAC), the Channel Islands National Marine Sanctuary and other marine resource management agencies and partners with information on strategies to control and manage the spread of the invasive Asian alga, *Undaria pinnatifida,* within (and adjacent to) waters of the Channel Islands National Marine Sanctuary (CINMS) and Channel Islands National Park.

The protected environment in the sanctuary supports unique and diverse marine habitats threatened by the introduction of invasive marine species that can arrive on ocean currents as well as local and visiting vessels. *Undaria pinnatifida* (hereafter *Undaria*) is one such invasive species that was recently introduced to the sanctuary and park.

As prescribed in Executive Order 13112 (February 1999), executive departments and federal agencies are mandated to take steps to prevent the introduction and spread of invasive species and support efforts to eradicate and control invasive species that have become established. Executive Order 13751 (December 2016), which amended Executive Order 13112, states: "[i]t is the policy of the United States to prevent the introduction, establishment, and spread of invasive species, as well as to eradicate and control populations of invasive species that are established."

Moreover, section 30230 within the California Coastal Act maintains that "[m]arine resources shall be maintained, enhanced, and where feasible, restored….[and] Uses of the marine environment shall be carried out in a manner that...will maintain healthy populations of all species of marine organisms..." Section 30231 within the California Coastal Act prescribes that "[t]he biological productivity and the quality of coastal waters...appropriate to maintain optimum populations of marine organisms...shall be maintained and where feasible, restored."

Federal regulations in place for CINMS (Code of Federal Regulations, Title 15, Sections 922.71 through 922.74) include a prohibition on the introduction of non-native species[1] into sanctuary waters (15 CFR 922.72(12)). Despite this, invasive species such as *Undaria* have been found in sanctuary waters. Therefore, strategies to contain, control, and slow the spread of *Undaria* must be identified and prioritized. Furthermore, preventative measures are needed to avoid future invasions by other non-native species altogether.

Sanctuary staff and partners have expressed an interest and need for a management strategy to eradicate or prevent the further spread of *Undaria*. It is important to note, however, there are few observations or experiments investigating how *Undaria* impacts its surrounding environment. Furthermore, given the invasive life history characteristics of *Undaria*, eradication of established populations is likely not feasible.

Section I of this report provides an overview of the global and local threat and expansion of *Undaria pinnatifida* and offers a suite of potential recommendations to address the management

[1] CINMS regulations at 15 CFR 922.71 define "introduced species" as "any species (including but not limited to any of its biological matter capable of propagation) that is non-native to the ecosystems of the Sanctuary; or any organism into which altered genetic matter, or genetic matter from another species, has been transferred in order that the host organism acquires the genetic traits of the transferred genes."

and control of *Undaria* in sanctuary waters. An assessment of outcomes, challenges, and management plans from other *Undaria* infested areas illustrates how *Undaria* may affect the sanctuary's marine ecosystem and presents options for the management of its spread. Sections II, III, and IV present case studies from Australia, New Zealand, and Monterey Bay, respectively. These case studies can guide effective, science-based policy, research and monitoring, and education and outreach recommendations to manage *Undaria* in sanctuary waters. Section V explores case studies of other invasive species that provide some potentially useful strategies to inform relevant recommendations for the management of *Undaria.*

The Sanctuary Advisory Council, a 21-member advisory body, provides community and interagency stakeholder advice to the CINMS Superintendent on a variety of sanctuary management issues. The opinions and findings of the Sanctuary Advisory Council do not necessarily reflect the position of CINMS or the National Oceanic and Atmospheric Administration. For more information on the Sanctuary Advisory Council, visit https://channelislands.noaa.gov/sac/welcome.html.

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Executive Summary

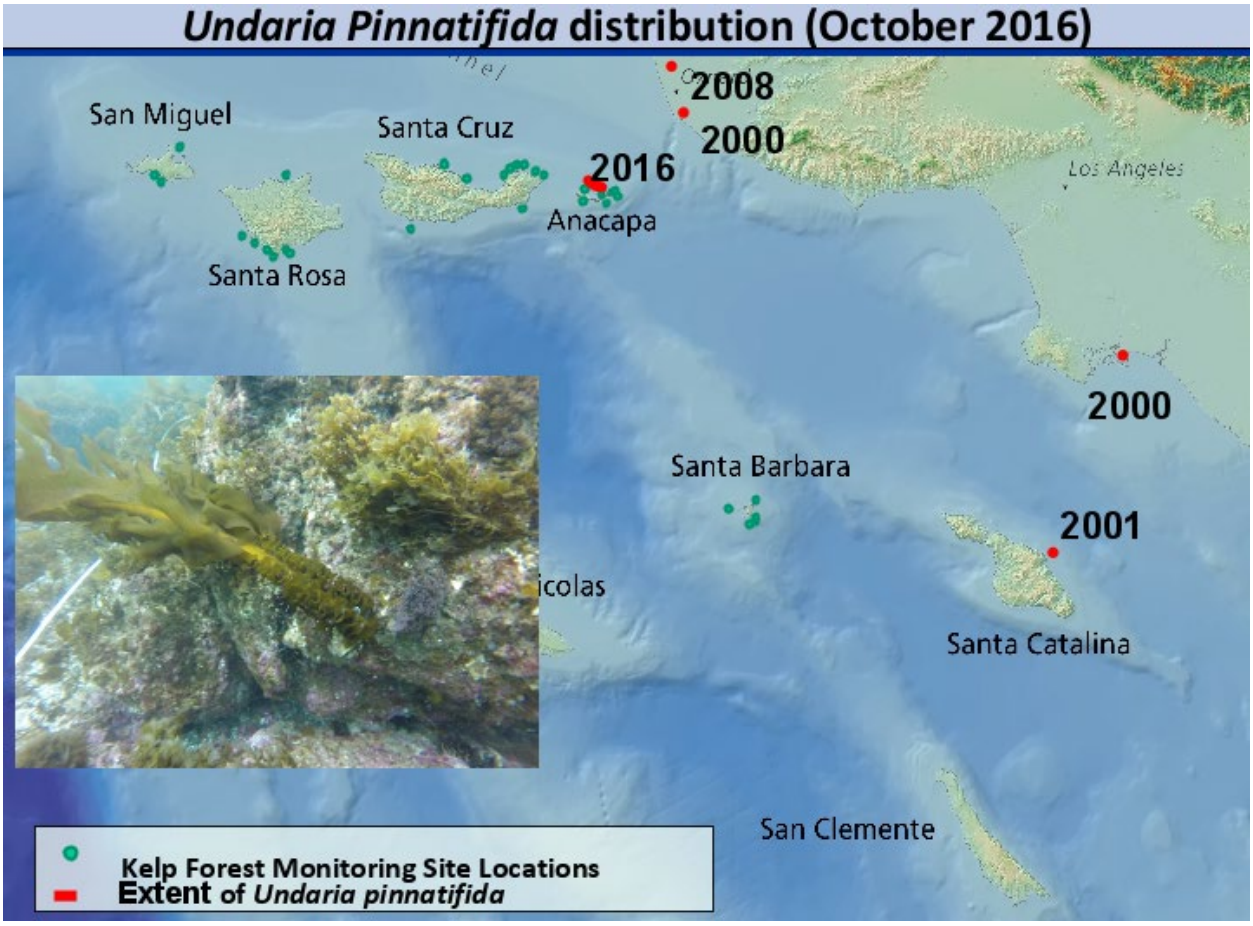

Figure 1. Red dots show identified *Undaria pinnatifida* populations around the Channel Islands. *Credit: Dave Kushner; Channel Islands National Park*

Problem Statement

Undaria pinnatifida, commonly known as wakame, is a Japanese alga native to the northwest Pacific ocean. This species is one of the most invasive marine pests, and is listed in the World Conservation Union's publication 100 of the World's Worst Invasive Species (Lowe *et al*., 2000). It is now widespread throughout the globe, inhabiting countries in every continent except Africa and Antarctica. The first record of *Undaria* spreading to areas beyond its natural habitat was in 1971 when it was accidentally introduced to the French Mediterranean coast by Japanese boats importing oysters (Boudouresque *et al*., 1984; Floc'h *et al*., 1991). It has since been recorded along the coasts of New Zealand (Stapleton, 1988; Hay, 1990), Australia (Sanderson, 1990), Argentina (Piriz & Casas, 1994), and along the Pacific coast of North America (Silva *et al*., 2002) and Mexico (Aguilar-Rosas *et al*., 2004).

The life history of *Undaria* suggests it may have competitive advantages over native species. Fletcher & Manfredi (1995) highlight studies that outline these as the ability to colonize new or disturbed rocky bottoms or floating structures, formation of a thick canopy over subordinate biota, ability to occupy a wide range of shores down to roughly 20 m deep, and an extended period of reproductive spore formation.

Predicting the ecological effects of *Undaria* is difficult because relatively few studies have examined how *Undaria* impacts the environment that it invades. Some observational and experimental research suggest *Undaria* reduces native algal species diversity and richness (Tasman sea; Valentine & Johnson, 2003; Casas *et al*., 2004; northeast Atlantic, Farrell & Fletcher, 2006) and structurally distinct and less diverse small-bodied invertebrate assemblages that rely on algae for their habitat (Arnold et al., 2016). Other experimental studies show *Undaria* does not have an effect on native seaweed cover (Forrest & Taylor, 2002; Tasman Sea, Valentine & Johnson, 2005; Raffo et al., 2009) and can add species richness and diversity by offering unique shelter and foraging opportunities for local prey in Argentina (Irigoyen et al., 2011). Nevertheless, existing studies suggest *Undaria* can change the composition and structure of the ecosystem it inhabits and affect flora and fauna abundance and richness, including within areas like the Channel Islands National Marine Sanctuary (CINMS) and Channel Islands National Park -- protected environments that support local businesses and entice visitors from around the country and world.

Many studies and failed eradication attempts indicate that once this species has colonized, it has been nearly impossible to eradicate due to its highly adaptable nature, microscopic life cycle phase, and ability to settle on most hard substrates. No country has effectively eradicated *Undaria* (with the exception of one isolated case off the coast New Zealand).

In British waters eradication was attempted but was unsuccessful since many of the manually removed specimens were already fertile (Fletcher & Farrell, 1999). In the Venice Lagoon, eradication was unsuccessful when removals were performed both during and after the reproductive period (Curiel *et al*., 2001). In a marine reserve in Tasmania, monthly manual removal of *Undaria* resulted in the next generation consisting of a considerably reduced number of smaller individuals, few of which reached maturity (Hewitt *et al*., 2005). But the only documented effective eradication was in New Zealand on the Chatham Islands located over 700 km from the mainland. Rapid response to the small-scale isolated invasion secured the success of *Undaria* eradication through a heat treatment method (Wotton *et al*., 2004). When *Undaria* was first spotted on the hull of a sunken ship, the Chief Technical Officer for Marine Biosecurity

authorized management efforts the next day. Divers removed spotted *Undaria* every thirty days for one year before deciding to heat treat the hull. The treatment took four weeks and monthly surveys continued for two years. In total, the eradication effort took over three years.

It is critical to implement unified action strategies as threats from introduced species in the 21st century will be high in the world's most developed economies (Early *et al*., 2016). Increased globalization and environmental change will pave the way for new introduced species to colonize more easily (Bradley *et al.*, 2011). A major lesson learned from the four case studies highlighted in this report is that effective management of invasives is enhanced with unified local and national agencies and governing bodies employing a shared management strategy to prevent further spread. Given that *Undaria* can rapidly mobilize (through human facilitation) and invade neighboring areas, control of its further spread within the Santa Barbara Channel region, including the Channel Islands, would require a focus on management and control efforts. Because of the connectivity of local harbors and marinas to the islands, an effective management strategy requires a network of entities working together to limit the invasion and prevent future introductions.

Given the recent discovery of *Undaria* in the sanctuary and the potential threats it poses to native species, this report focuses on management strategies and recommends actions to limit the spread and future introduction of *Undaria* in the Santa Barbara Channel and sanctuary.

Natural History

Effective management strategies for *Undaria* requires an understanding of its natural history. It can reach lengths up to 3 meters and colonize on hard substrates up to depths of 20 meters. *Undaria*'s life cycle consists of two phases: a diploid sporophyte (figure 2; the spore producing plant) and a haploid microscopic gametophyte. The sporophyte can develop from autumn to winter through mid-spring. In the spring, they release spores that will develop into gametophytes during the summer. The spores that develop into gametophytes settle on hard surfaces and can then be fertilized. Temperature, light, and depth will affect the develop of the gametophyte.

Undaria is an annual species and can be found in a wide range of water temperatures from 0 to 27 ºC and a range of salinity levels from 20-34 practical salinity units (PSU). Optimal temperature for maturation is between 10-15 ºC (Morita *et al*., 2003). For context, Channel Islands water temperature may vary from 10 to 22 ºC (lower 50s to lower 70s degrees fahrenheit) dependent upon the season and sea surface salinity levels typically average 32 - 33 Practical Salinity Units (PSU).

Regional Context

Undaria pinnatifida was first spotted in 2000 in the Los Angeles Harbor. In 2001, aggregations were found in Santa Barbara Harbor, Cabrillo Beach in San Pedro, Channel Islands Harbor at Oxnard and at Santa Catalina Island. In 2003, the species continued to spread northward and into Monterey Bay where control and prevention efforts were initiated upon discovery. In 2009, it was discovered in a marina in San Francisco Bay. In 2016, *Undaria* was found off the north side of Anacapa Island by divers from the Channel Islands National Park (see Figure 1). During follow-up monitoring dives led by the Channel Islands National Park in 2017 and early 2018, *Undaria* was confirmed off Anacapa, but no other sightings have been reported/verified from other locations within the northern Channel Islands.

The rapid and long-distance dispersal of this species is most likely due to local boats and international ships travelling back and forth from affected to unaffected ports and harbors (Zabin *et al*., 2009). Microscopic gametophyte stages can be transported in ballast water, while sporophytes (plants) can grow on boat hulls. Once established, populations are slow to spread naturally along shorelines or in natural sublittoral habitats (Farrell and Fletcher, 2006). Sporophytes can naturally disperse up to 100 meters per year, depending on surrounding environmental conditions (Forrest *et al*., 2000).

Case Studies Overview

The case studies in the subsequent sections focus on the monitoring, prevention, and control of *Undaria pinnatifida* in countries working to manage it. The first study examines the actions and programs implemented by the Australian Government. The second study focuses on the actions and programs implemented to control *Undaria* in New Zealand. The third study describes the strategies of the Monterey Bay National Marine Sanctuary to control and eradicate the spread of *Undaria*. Lastly, management strategies of other invasive species were compared to gain knowledge of best practices applicable for this marine invader.

Each of the mentioned case studies include a summary of the range of research and monitoring projects, education and outreach initiatives, and regulatory actions pursued to slow the spread of invasive species and prevent new invasions. While some strategies mentioned are specific to *Undaria*, some are also relevant to prevent invasions of other introduced species like *Sargassum horneri*.

Recommendations for the Santa Barbara Region

Through research and suggested recommendations by other institutions and agencies with knowledge and experience on managing invasive species, sanctuary staff encourage the consideration of the following management strategies for *Undaria pinnatifida.*

First, managers should document the magnitude of the invasion to determine how the invasion should be addressed. Then, clearly defined objectives can help determine the extent of control and monitoring required and appropriate strategies to manage it. Following an analysis of literature, the management recommendations below seem suitable for the Channel Islands, in addition to other regions and partners mentioned in this section (in order of feasibility):

- Expand education and outreach efforts to increase boater awareness;
- Continual monitoring of docks, anchorages, piers, and boats (monthly, if possible);
- Identify and protect high value areas from invasion through targeted monitoring efforts;
- Subtidal monitoring at least three times per year of identified hotspot areas;
- Conduct studies on how *Undaria* affects local ecology;
- Prevent further spread through monitoring and containment of existing populations and rapid removal response to newly invaded areas;
- Explore policy options to enhance clean boating practices;
- Explore biosecurity regulations for vessels identified as potential vectors;
- Create an early-response team for removal of early-detected sporophytes.

Long-term Research

The sanctuary and partners may benefit from conducting research on how this invasive species is affecting local flora and fauna. Some research has already been conducted in the Monterey Bay National Marine Sanctuary but because their invasion is specific to docks, *Undaria* may have a different impact within the more open waters surrounding the Channel Islands. In addition to surveying invasion effects, researchers can investigate the most optimal way to remove newly spotted species to avoid spore release. Disposal of the removed algae should also include research on alternative uses for the removed material that are more eco-friendly than disposing algae in landfills.

Experimental and manipulative experiments characterizing how *Undaria* affects the native ecology on the islands could be coupled with less resource-intensive management to prevent spread. Once results show ecological impact then partners can reassess appropriate management strategies moving forward.

Vector Management

One of the most effective methods for controlling the spread of the *Undaria* and other invasive species is through the use of regulations or policies supporting vector management in designated high value areas (defined in section III). Potential policies that can address the following practices may reduce the likelihood of new introductions of *Undaria* and its spread into surrounding areas:

- Gear such as diving equipment, fishing traps, anchors, and other gear that may be in the water for an extended period of time (recreational/commercial) must be thoroughly cleaned before and after every use;
- Control points: conduct inspections of gear and vessels to check for fouling;
- Hull de-fouling executed some specified distance away from high value areas and ports;
- Continual vector monitoring and partnership with the U.S. Coast Guard;
- Hulls should be regularly cleaned or have antifouling agents on them:
    - Sea nine 211^{TM} and a red algal extract (Furanone 281) at concentrations >1.6 mg l^{-1} and 40 mg l^{-1}, respectively, can result in the mortality of *Undaria* gametophytes and can be used as a chemical control (Burridge and Gorski, 1998).
    - Ideally, boats should be cleaned after every use and dried at least after every five days if stored on land. If stored in the water, boats should be checked yearly to determine if antifouling paint should be reapplied.

A preventative plan, as mentioned in Section III, can outline regulations and suggestions to better manage vectors going into and out of the Channel Islands and nearby mainland harbors. One option to manage vectors is through the use of a clean vessel pass. If implemented, a vessel entering the CINMS within one mile of an island (also Park jurisdiction) would be expected to carry the pass. Boaters applying for the pass should meet certain requirements for cleanliness of their vessel's hull, including when it was last washed and anti-fouled. An example of a simple application taken from Fiordland National Park in New Zealand can be found in Appendix A.

Target boaters for this clean vessel pass may include public, private, and commercial boats frequenting the area. In Fiordland, boaters apply for the pass on a yearly basis. The use of this pass would be beneficial not only for preventing further *Undaria* introductions but also preventing introductions of other marine invasive species.

Assuring compliance with these types of requirements may necessitate the creation of a vector monitoring team, if no other enforcement options exist. Responsibilities for a vector monitoring team may include: government funded monitoring of vectors within the sanctuary, ensuring vessels comply with current discharge regulations (i.e. introducing *Undaria* is a form of discharge) a partnership with the Coast Guard in support of inspecting hulls and monitoring ballast water discharges to ensure ships do not illegally discharge within high value areas, and prohibiting wild harvest and farming of *Undaria*. Such a monitoring team, working in coordination with the rapid response team (mentioned below), would enable the successful management of *Undaria*.

If sustaining a vector monitoring team proves unfeasible, the clean vessel pass could include a chip that can be identified by radar to show the vessel has met cleanliness standards. This would make enforcement easier by identifying which boats have a chip or not; therefore, enforcement personnel do not have to check every boat every time. While this report does not prescribe that this program be implemented, it does suggest exploring policy options to manage vessels visiting the Channel Islands[2].

Commentary from California State Lands Commission staff recommends working with federal, state, and local agencies to incorporate measures in their authorizations/permits for projects utilizing vessels (including barges and anchors) and construction equipment in the Santa Barbara region to reduce the spread of *Undaria* and other invasive non-native or nuisance species. For example, Commission staff includes measures in their environmental documents to control the spread of invasive non-native or nuisance species, including:

- Requiring that project vessels originate and are based out of specific harbors, at least since last dry docking.
- Requiring that underwater surfaces of vessels and other construction equipment be cleaned before entering the project region.
- Requiring that ballast water for all project vessels, regardless of vessel size, be managed consistent with the Commission's ballast water and biofouling management regulations, including submission of the Marine Invasive Species Program Annual Vessel Reporting Form to Commission staff.
- Making project vessels be available for inspection by Commission staff for compliance.
- Holding a training for project personnel by a qualified, Commission staff-approved marine biologist about the spread of nonindigenous species in California waters and the State's programs.

The State Lands Commission in partnership with the California Department of Fish and Wildlife and California State Water Resources Control Board may serve as opportune agencies responsible for creating and implementing biosecurity plans for the state of California. These biosecurity plans and management strategies may also be supported by the Invasive Species Council, California and the California Invasive Species Advisory Committee, the EPA, and USCG (Muir, 2011). The EPA has the authority to enforce the Clean Water Act for invasive species regulations and the USCG under the authority of the National Invasive Species Act can enact policies to stop invasive spread. In Western Australia, the Department of Fisheries is responsible for awareness campaigns, strategic research, policy development, and monitoring of high risk ports for potential pest invasion

[2] The recreational fishing seat of the SAC expressed the concerns of his constituency if some of the suggested vector management strategies were implemented.

in collaboration with other involved agencies and stakeholders (Piola & McDonald, 2012). Sanctuaries and Parks are also adept at creating educational material to broaden the outreach.

Additionally, the California Coastal Commission certify Port Master Plans, serving as a natural entry point to work with ports throughout the state (Chela Zabin from the SERC mentions the importance of targeting major recreational ports; pers. comm.). The CCC also issue Coastal Development Permits to harbor districts and private entities for piers, docks, bulkheads, etc. As shorelines are increasingly altered to adapt to sea level rise (necessitating a CDP) and warming sea surface temperatures facilitate invasion into new areas, we might consider these as vulnerable and for which, could require due attention. It may be possible to use permit conditions to incorporate notification practices that help populate a database informing response teams, require BMPs, specifically include *Undaria* in monitoring plans, explore mitigation options, and/or require interpretive signage where appropriate (Lauren Garske-Garcia, pers. comm.).

Removal of Sporophytes

In sanctuary waters, eradication of *Undaria* from currently observed locations near Anacapa Island is likely not feasible given the magnitude of the spread, the time passed since its establishment, and the high probability of reintroduction through the continuous visitation of boats from neighboring *Undaria* infested ports. However, if new aggregations of *Undaria* are detected early enough (i.e. before they reach maturity) and aggregations are isolated, efforts to eradicate in these cases may help to control and manage spread. Because the sanctuary is so large (1,470 square miles of ocean and approximately 198 miles of shoreline) early detection efforts could target certain, identified and agreed upon high value areas (see Section III).

When considering methods of removal, heat treatments are the most effective for isolated and early-detected cases as it ensures the death of the microscopic spores (methods found in Wotton et al. 2004). However, heat treatment removal efforts should be tested to assess any impacts to adjacent species. Removal using a suction device is also an effective method as this captures small fragments of an individual (Marks *et al.,* 2016). However, suction may be harmful to neighboring species, does not promise removal of microscopic spores, requires a large amount of effort, does not guarantee eradication, and is only practical for protecting small areas. Any efforts to try control measures will need to be closely monitored to avoid or minimize impacts to native species and for effectiveness of the effort, and any removal effort would a require a Scientific Collecting Permit or a Letter of Authorization from the California Department of Fish and Wildlife.

The disposal of removed algae is an important issue. Other removal projects have taken algae waste to landfills or given it away to local farmers who use the nutrient-rich material as fertilizer. Other, eco-friendly options should be explored and researched.

Because *Undaria* removal efforts in the sanctuary would likely not result in eradication, removal is not a viable stand-alone option to manage this species. However, removal performed in conjunction with monitoring, early detection, and early response, may enhance the success of controlling and slowing the spread of the introduced species (mentioned below in *Continual Monitoring*).

For instructions on how to best manually remove *Undaria*, Dietrich & Lonhart (2010) suggest to cut below the meristem as the fastest, most effective method. To aid in the removal of invasive species, other countries and states have recruited volunteers or employed divers are sometimes

recruited (e.g. citizen science projects in San Francisco Bay). Within the sanctuary, removal efforts may be conducted by appointed groups (staff, volunteers, or student researchers, etc.) and approved by the sanctuary (if within sanctuary waters).

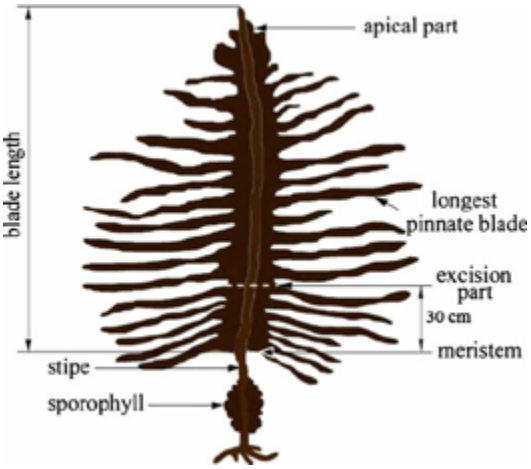

Figure 2. Diagram of *Undaria pinnatifida* showing where the meristem is located. Credit: Gao *et al*., 2012.

Additionally, partnerships with other agencies across the state will better influence the effectiveness of removal and control tactics to prevent or slow the spread. Some examples of other agencies that have participated in previous management and sighting programs in the state of California include: Elkhorn Slough National Estuarine Research Reserve, University of California (UC) Santa Cruz, Moss Landing Marine Laboratories, California Department of Fish and Wildlife, State Lands Commission, California Coastal Commission, Monterey Harbor Master's Office, City of Monterey Volunteer Services, UC Davis, Smithsonian Environmental Research Center (SERC), National Oceanographic and Atmospheric Administration (NOAA) Southwest Fisheries Unit, California Department of Boating and Waterways, California Fish and Wildlife, California Coast Keeper Alliance, Western Regional Panel on Aquatic Nuisance Species, California Sea Grant offices along the coast, and dive clubs.

With only one case of successful eradication of *Undaria* in the world documented within the past 46 years since it has been considered invasive, eradication is highly improbable. Complete eradication from the Channel Islands is also unlikely given the location, magnitude of the spread, and constant vector movement. Therefore, prevention strategies and slowing of *Undaria's* spread is the most cost effective and ecologically protective approach to managing this invasive species compared to relying on constant efforts to remove *Undaria*. Additionally, having an invasive species management plan in place can be useful for future aquatic invasions, organizing and guiding response more efficiently and effectively.

Continual Monitoring

As with most other management strategies, continual monitoring and surveillance is essential to prevent the continual spread of *Undaria*. An ideal continual monitoring program would include:

a. Monitoring to detect pest incursions as soon as possible (and to subsequently dispatch an emergency response team).

b. Ongoing monitoring to support a domestic ballast water management system aimed at reducing the risk of port-to-port spread within California.
c. Monitoring to record changes to the marine environment.
d. Monitoring to determine how well prevention measures are working.
e. Financial support from the creation and maintenance of a rapid response fund.
f. Creation of a rapid response notification database.

The Kelp Forest Monitoring team, led by the Channel Islands National Park, was responsible for initially sighting *Undaria* in 2016 near Anacapa Island, and making return trips to check on its development. The Kelp Forest Monitoring Program was established by Channel Islands National Park in 1982 to collect baseline information about the kelp forest ecosystem in the Park, each year repeatedly collecting size and abundance data for 70 taxa of algae, invertebrates, and fish. This invaluable program, with its long-term baseline dataset, has been and promises to continue to be essential for detecting changes in the Park's kelp forest ecosystems, including detection of *Undaria* spread in the vicinity of established monitoring sites (see Figure 1 above) and the ability to call for response.

Additionally, the dive team at CINMS performs a variety of dive trips for research and monitoring projects throughout the year,and can also contribute to efforts to confirm possible sightings of *Undaria* or monitor possible spread. Their work aids in the production of outreach messaging to reach sanctuary visitors that may make direct contact with *Undaria* hotspots. Joint efforts between agency divers and visitors will be more effective for detecting and monitoring new and expanding *Undaria* populations.

Upscaling continual monitoring and early detection efforts is costly and requires ample resources. Dive volunteers, area researchers, and others who spend a significant amount of time in sanctuary waters can be targeted for receiving detection training (one potential partner could include Reef Check California). If species are introduced or identified in an area, key partners should create a response plan by evaluating the feasibility of eradication or other management options to limit spread. Goals of continual monitoring should include seasonal dives to high value areas, particularly before *Undaria* maturation, and ongoing dives to affected areas and new areas to determine spread and potential impacts. *Undaria* have seasonal reproduction with growth in the winter and release of spores during the spring/summer months. Dives performed during the winter months may best capture new *Undaria* aggregations.

New research indicates the probability of finding *Undaria* on rocky reef increases with increasing proximity to marinas with high abundances of *Undaria* (Epstein & Smale, 2017). Monitoring teams might then focus on ensuring piers and dock structures within the Channel Islands National Park do not become infested, which could in turn propagate spillover of the infestation into neighboring habitats (harder to manage).

The creation of an emergency response team can help address the invasion of *Undaria* into new areas, follow outlined objectives and protocols on how best to proceed, and document actions taken. An emergency response team would work to prevent spread by controlling and/or quickly removing new aggregations in new areas before maturation, if possible. A fast response is key and could also help eradicate *Undaria* from a specific new area, especially if the invasion is small and isolated.

As seen through the swift and coordinated efforts of multiple agencies in the eradication of *Undaria* on the Chatham Islands (Wotton *et al*., 2004), an organized effort reaching all affected (and unaffected) areas and involving relevant agencies with jurisdiction along the California and/or west coast can ensure that implementation of a shared management plan will have the greatest likelihood of success. Because *Undaria* can spread rapidly over great distances through vector transport, it is necessary to have similar, enforced control and management strategies coast-wide. By combining efforts, it will make it easier to prevent, or at least slow the spread of the alga. Adopting a state action plan could help make decisions transparent, consistent, and well-documented.

These targeted monitoring and response efforts may also aid in the discovery of potential new invasions of other marine invasive species and do not have to be specific for *Undaria*.

Education and Outreach

Measures of outreach and education (O&E) are important for keeping boaters, divers, and other ocean users informed about this alga, its characteristics, and methods to help prevent its spread. O & E may serve as an initial step to implementing an invasive species management plan as it is not resource intensive and targets the audience most likely responsible for spread (boaters). In coordination with and support of partners that have relevant experience with education and outreach on introduced marine species (e.g., Dr. Carrie Culver, California Sea Grant), sanctuary staff have already taken some initial outreach steps to inform users about this alga. Continual O&E efforts are essential to creating awareness and aiding in early detection. Goals for outreach and education should include:

a. Promoting prevention and response. Users of the marine environment should receive information (e.g., written and visual materials) about *Undaria* that clearly explains preventative measures individuals can take to detect and avoid transporting *Undaria*, and recommended response actions (e.g., reporting, handling) to take if *Undaria* is spotted.
b. Aiding in the ceasing or slowing of the spread into other islands and surrounding areas.

In support of these goals, posters that are already distributed by various agencies and organizations include the following:

- *Undaria pinnatifida* Identification Guide (Appendix B)
- Identification and Reporting Flyer (Appendix C)

Flyers, posters, and watch cards will make the most impact when distributed to agencies involved in the management network, marine resource users (marinas, dive shops, kayak rentals, boating classes, hull cleaning providers, etc.), and at boater conventions. Chela Zabin, a researcher for the Smithsonian Environmental Research Center, notes that one of the best forms of outreach in her experience is through presenting the actual specimen at boater conventions because people often mistake other algal species as *Undaria* (pers. comm.).

Affected areas should adopt uniform and consistent outreach messaging and coordination of efforts. Primary messages might focus on preventative cleaning measures, what to do if *Undaria* is found either on/in someone's boat/gear, and how one should report it. More targeted messaging for the Channel Islands may include proper cleaning strategies for anchors as *Undaria* are found in deeper waters.

Through the U.S. Fish and Wildlife Service (USFWS) Aquatic Invasive Species (AIS) Regional Coordinator, messaging about *Undaria* could be incorporated into state distribution and outreach efforts. Assigned by the USFWS in their Region 8, the AIS Regional Coordinator connects multiple agencies and stakeholders, both public and private, to create a network to fight or cease the spread of aquatic invasive species to unaffected harbors and habitats.

Additionally, participation by the sanctuary and partners in platforms such as the Stop Aquatic Hitchhikers campaign can aid in preventing invasive spread. This website already has over a thousand partners and members, reaching recreational boaters on a wide scale. More locally, programs such as Dockwalkers can get volunteers involved in sharing aquatic invasive information. The California Coastal Commission also have a public education department and grant programs that may be of potential interest. These partnerships and communication channels may also be of use when other, future marine invasions occur.

Concluding Remarks

The above recommendations include a range of options that could work in conjunction with one another to effectively stop or slow the spread of *Undaria*. While *Undaria* eradication is improbable, monitoring, education and outreach, early detection, and vector management engages the problem from multiple sides. These methods are also used by other countries (mentioned in subsequent sections) to manage the spread of *Undaria*.

Because of the high mobility and adaptive characteristics of *Undaria*, it is not recommended that management strategies be used in isolation by the Sanctuary and Park; rather, agencies and stakeholders along the coast would do well to use and enforce a single management scheme to implement some (or all) of the above suggested recommendations. Should one area not manage the species, while another area takes effort to control it, *Undaria* will inevitably spread because of boater traffic between docks and ports.

Ultimately, effective organization for management of this species would involve multiple agencies, including local, state and national, across Western states. Through active participation and employment of protocols by all agencies involved, we can stop the spread before it becomes a problem, as in the Quagga and Zebra mussels case described in Section V. Through implementation of preventative strategies and creation of a network of coastal partners, we may also combat other, future marine invasive species. See Appendix D for a summary table of preliminary action items[3].

[3] The SAC alternate recreational fishing seat suggested a cost benefit analysis of specific options for the Santa Barbara Channel region should be further explored before implementation.

Marine Invasive Algae Partners

CDFW's Marine Invasive Species Program (MISP) within the Office of Spill Prevention and Response (OSPR) posts monitoring data on the internet, updates the data on an annual basis, and submits a report to the Legislature detailing the results of the monitoring. MISP coordinates with the California State Lands Commission to control the introduction of Non-Indigenous Species (NIS) from the ballast of ocean-going vessels.

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Invasive Species Council of California - The ISCC is an inter-agency council that helps to coordinate and ensure complementary, cost-efficient, environmentally sound and effective state activities regarding invasive species.

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David & Lucille Packard Foundation – invests in action and ideas that conserve and restore ecosystems while enhancing human well-being.

Reef Check- citizen scientist divers who volunteer to survey the health of the rocky reef ecosystem along the coast of California
Jan Freiwald – Executive Director
Jennifer Mihaly – Operations Manager
Selena McMillan – Southern California Regional Manager

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Section II

Australia National Control Plan

Figure 3. *Undaria pinnatifida* specimen.

Introduction

In 1988, *Undaria pinnatifida* was found along the coast of Tasmania, Australia for the first time and was thought to have been introduced by ballast waters from ships travelling from Japan (Sanderson, 1990). Since then, *Undaria* has spread along Tasmanian and mainland coastlines such as Hobart, Port Phillip Bay, Victoria, and Apollo Bay. As an ongoing effort, Australia continues to expand and update control plans for marine pests.

Management efforts to eradicate *Undaria* in several ports have failed, as the microscopic phase of its life cycle makes it nearly impossible to rid the area completely. Various chemical, physical, and biological methods of eradication have been tested, but only one anti-fouling agent has been successful for killing both the sporophyte and gametophyte life stages. As a result, most control options for this species in affected and non-affected areas is to prevent spread or introduction into new areas. An important aspect of eradication or control is early detection of invasive species.

Management Actions

The Australian National System has three major components:

1. *Prevention*: Prevention systems to reduce the risk of introduction and translocation of marine pests (including management arrangements for ballast water and biofouling).
2. *Emergency Response*: A coordinated response to early detections.
3. *Ongoing Management and Control*: Managing already introduced marine pests.

The National Introduced Marine Pest Coordination Group (NIMPCG) established Australian marine pest monitoring guidelines in 2009. Members have agreed upon a minimum number of locations at which ongoing monitoring must take place. This group coordinates with the Invasive Marine Species Program in the Department of Agriculture, Fisheries, and Forestry (DAFF). DAFF stores and analyzes the monitoring data and participates in approval processes for survey designs and implementation plans as a key member of the Monitoring Design Assessment Panel (MDAP).

Within each of the monitoring sites are specific vector 'nodes' to be monitored and managed by the jurisdiction in charge, for example the Port Authority, local council, or other private organization. The vector 'nodes' include: commercial trading port (wharves, anchorages, channel, tug base/pilot base, bunker and barges, other services, patrol boats, and navy areas), marinas, boat ramps, recreational anchorages, boat yards, slipways, dry docks, aquaculture leases, ferry wharves, and navigational buoys (NIMPCG, 2009).

To standardize and better facilitate the monitoring process, the NIMPCG uses survey design programs such as their already developed Monitoring Design Template (MDET) which provides outputs for key aspects of the survey to meet minimum requirements; it is used to determine the target species list, observation systems, sample sizes, and survey costs. A standard sampling log and monitoring data input sheet is used to ensure data is uploaded to the national monitoring database.

The Australian Emergency Marine Pest Plan considers the eradication of invasive species already established in open marine environments to be impossible. In these cases, the plan recommends a combination of strategies to minimize the spread and impact of established marine invasive species. These include:

- Establishing declared areas to define zones where the pest is present or suspected to occur, and where emergency management operations are to be implemented.
- Quarantining and restricting or controlling movement of potential vectors, such as submersible equipment, vessels, marine organisms (fauna and flora) and ballast water in declared areas to prevent spread of the pest.
- Decontaminating potential vectors for the pest, *e.g*. vessels, aquaculture stock, and maritime equipment, or water that may contain sporophytes.
- Treating established populations on natural and artificial habitats in the infested area.
- Conducting surveys to determine the source and extent of the incursion.
- Surveilling and monitoring to provide proof of freedom from the pest in adjacent waters.

A review of Australia's National Monitoring Strategy (2015) includes several recommendations for the continual management of invasive species. These recommendations include: (1) creating a more effective early warning system with frequent monitoring of hot spot areas; (2) monitoring to support domestic ballast water management system aimed at reducing the risk of port-port spread within Australia; (3) monitoring at a few ports or invaded areas to record changes in the marine environment, including the presence of invasive marine species; (4) monitoring to determine how well prevention measures are working.

Australia has also implemented measures to reduce hull fouling, which only apply to vessels under 25 meters in length and are in the process of becoming mandatory. These measures include: (1) cleaning the vessel's hull within one-month prior to arrival; (2) applying antifouling paint within one year prior to arrival; (3) booking the vessel to be hauled out and cleaned within one week after arrival.

Australia is one of the few countries focusing on ballast water requirements to protect their marine ecosystems and prevent further introductions. Without ballast water regulations, water is often released in ports. Their regulations are outlined in the Australian Ballast Water Management Requirements. While these measures are geared towards larger ships, some of these measurements could be used for smaller vessels as well and be incorporated into the requirements for a "Clean Vessel Pass" (mentioned in Sections I and III).

Analysis: Potential Applications for the Santa Barbara Channel Region

Similarities

Undaria pinnatifida invasions around the world often occur exclusively in ports or marinas. However, *Undaria* has invaded also waters along the open coast of Australia (in addition to ports) similar to open-coast reefs around the California Channel Islands. These conditions may merit alternative management strategies. Australian management strategies focus on the prevention of further introductions into nationally owned waters, in addition to monitoring and removal of any known sporophytes aggregations where invasion is detrimental to native ecology.

Australian management strategies would be useful to employ in responding to early-detected open-coast incursions and for avoiding port to port spread in California.

Differences

Most of the focus of management strategies proposed by the Australian government is meant for larger ships or commercial traffic. The Channel Islands receive both recreational visitation and

local commercial vessel traffic. Determining the incidences of ballast water release in the Santa Barbara Channel or surrounding area is outside the scope of this management report but could be further explored to reduce introductions near high traffic ports.

Most notably, the Australian government recognizes the importance of reducing the likelihood of invasions because of a long history of dealing with species introductions. Australia has allocated resources and has ample experience in dealing with invasive species. Australia has a great network of agencies that coordinate with each other to stop or prevent invasions and are continuously modifying their biosecurity regulations to amplify their preventative success.

In California, such coordination does not yet exist to manage the spread of *Undaria*. However, efforts to control other aquatic and terrestrial invasive species within the California do exist. Similar coordination could also be achieved to manage the invasion of *Undaria* if agencies realize the importance of involvement in preventative strategies and prioritize the issue.

Opportunities and Recommendations

Australia expended many resources attempting to eradicate *Undaria*, through use of biological, chemical, and physical control methods, but without success. Their most recent strategies reflect this trial and error process by focusing more of their efforts on containment of the spread and management of vectors.

A few recommendations stemming from Australian management strategies and lessons are to primarily focus efforts on controlling vectors and monitoring areas already invaded to ensure the species is contained within already invaded locations and not spread to neighboring areas. As a start, creation of emergency response team can assess the nature and extent of the incursions and help to determine what control measures should be taken.

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Section III

New Zealand Undaria management plan

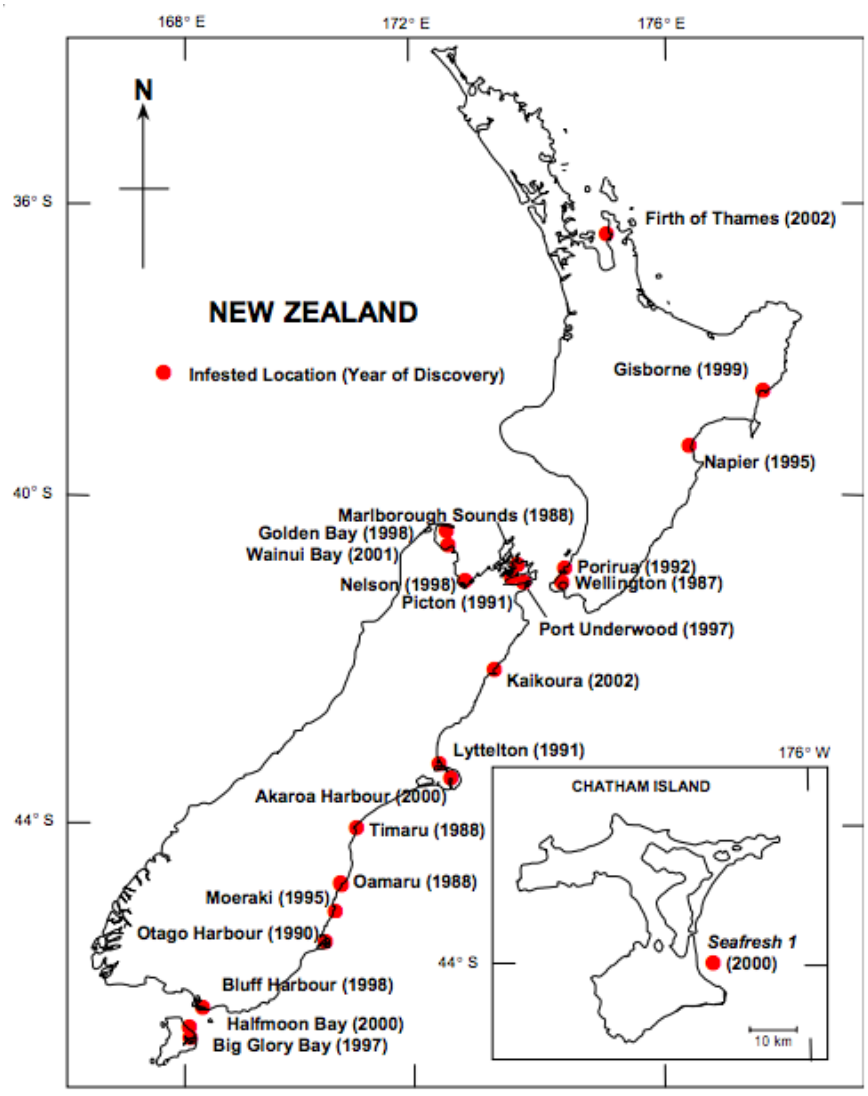

Figure 4. Red dots symbolize the documented areas of spotted *Undaria pinnatifida. Source: Stuart, 2004.*

Introduction

In 1987, scientists first discovered *Undaria pinnatifida* in Wellington, New Zealand and it has since spread to other mainland coastal areas in New Zealand including many ports (figure 4; Hay & Luckens, 1987). In 1993, the New Zealand Biosecurity Act deemed *Undaria* an unwanted species and has included it in several pest species management plans. *Undaria* became an ecological problem for several areas along the New Zealand coastline, and has great potential for invading further due to the water climate conditions which are optimal for *Undaria* growth.

Management Actions

In 2016, New Zealands Conservation Minister announced to the IUCN Conservation Congress that NZ will take a leadership role to work with partners to increase global efforts to control and eradicate invasive species. Within NZ, the New Zealand Oceanographic Institute, Department of Conservation, Cawthron Institute, National Institute of Water and Atmospheric Research, The Ministry for Primary Industries, The Ministry of Fisheries, various universities, and local government and stakeholder groups created, maintained, and modified invasive species management plans for the protection of their waters against marine pests.

Initial attempts to rid waters of *Undaria pinnatifida* involved using chemicals on floating structures (e.g. buoys) that could serve as potential fouling sites for *Undaria*. These methods proved ineffective, however, and the Department of Conservation instead focused their efforts on heat treating an invaded site off the coast of the Chatham Islands.

Since spotting *Undaria* off the coast of the Chatham Islands, divers removed plants and surveyed every thirty days for about a year until they heat treated the entire hull to kill plants and the microscopic gametophytes. The heat treatment took about four weeks, and divers continued to monitor the area for the next two years until they deemed *Undaria* was successfully eradicated.

Heat treatment involves encapsulating the *Undaria* and heating the water within the capsule. Wotton et al. (2004) effectively eradicated *Undaria* from the hull of a sunken ship through surrounding the *Undaria* with a wooden box, heating the water up inside the box with elements for ten minutes, and then moving to another section of the boat. This method worked; it is the only known case of eradication of *Undaria* in New Zealand.

In the published report of this heat treatment, Wotton et al. (2004) mention the "Ministry of Fisheries, the lead agency for marine biosecurity in New Zealand, undert[ook] a qualitative risk assessment using information from a range of experts. The assessment determined that the presence of *Undaria* on *Seafresh 1* posed a sufficient threat to the environment, economy and social values of the Chatham Islands to warrant a response. Three main factors contributed to this decision: the invasive nature of *Undaria*; the demonstrated absence of *Undaria* from the Chatham Islands; and the unique and pristine nature of the Chatham Islands and their biota."

The Final Report written for the Ministry of Fisheries in New Zealand outlines the most imperative, economical, and effective management strategies. In general, the researchers recommend finding measures to minimize spread. This consists of managing human activities (vectors) to reduce the risk of transferring *Undaria* to uninfested areas. Secondly, surveillance and response are important measures in monitoring for new infestations, which are then subject to eradication or control.

Their management framework includes the following measures:

- Surveillance and response to new infestations in High Value Areas (HVAs) (including Locally Significant Areas);
- Intensive vector monitoring in key donor areas, targeting vessel fouling in particular;
- A prohibition on persons knowingly spreading or introducing *Undaria*;
- Controls on ballast water discharge and hull de-fouling in or near HVAs;
- Controls on wild harvest, farming, and research involving *Undaria*;
- Education and public awareness campaigns, including (where relevant) codes of practice for marine farmers, yacht owners/operators, and others.
- Research on impacts, improved management techniques, and other topics.

In New Zealand, they have identified HVAs. HVAs include marine protected areas, marine reserves, national monuments, heritage areas etc. These areas are particularly protected because invasions could cause significant impacts to them on all economic, social, and ecological levels. During a risk assessment survey, over half of experts agreed an invasion in HVAs would have a moderate impact on biodiversity, a moderate impact on trophic interactions, and a moderate to major impact on the habitat (Campbell and Hewitt, 2013). Another interesting point was that Undaria invasion would majorly influence aesthetics and diving.

Additionally, the Ministry of Fisheries provides advice for reducing the spread of *Undaria*:

- Apply anti-fouling paint to boat's hull regularly.
- Regularly clean hulls in a facility with collection and land-based disposal of fouling material, preventing fouling from returning to sea.
- Clean fishing and aquaculture gear thoroughly and away from the sea before using it in a new locality.
- Prevent the buildup of fouling on buoys by allowing them to dry out occasionally.
- Support the *Undaria* management initiatives in your area.

A study done in New Zealand by Hunt *et al*. (2009) showed that monitor and control programs can effectively control the spread of *Undaria* through regular and directed harvest of sporophytes. Management effort focused on protecting HVAs; the government is financially responsible for surveillance, response, education, and enforcement while private individuals and enterprises are responsible for research and a combination of mandatory and voluntary vector controls. The manual removal program in New Zealand costs approximately NZ$500,000 per year and includes vessel monitoring and cleaning costs.

In the Fiordland Marine Area (FMA) in New Zealand, the Southland Regional Council, consisting of representatives from Environmental Southland, the Fiordland Marine Guardians, Kai Tahu Oraka/ Aparima Runaka, and the Ministry for Primary Industries and Department of Conservation has implemented a plan to prevent the introduction of marine pests within one mile of the coastline (Fiordland Marine Regional Pathway Management Plan). Below are a few requirements for Fiordland Marine Area outlined in their management plan:

- Requiring the owner or person in charge of a vessel entering or operating within the area within one nautical mile of the landward boundary of the FMA to hold a Fiordland Clean Vessel Pass to assist with vessel operator knowledge and identifying higher risk vessels.
    - Application example can be found in Appendix A.
- Implementing clean hull, clean gear, residual seawater standards, and bilge water

procedures.

- Implementing a communications plan to ensure that owners or persons in charge of vessels entering the area within one nautical mile of the landward boundary of the FMA understand the rules and the reasons for them.
- Monthly hull inspections to assist with vessel operator knowledge and identifying high-risk vessels.
- A compliance and enforcement program to ensure that non-compliant vessels are identified and corrective action is taken.

Undaria was first found in Fiordland in Sunday Cove, Breaksea Sound in 2010. Since then, over $1 million has been allocated to the monitoring and removal of any and all *Undaria* individuals, with the intention of eradicating *Undaria* from the region altogether. However, even with their extensive management plan and preventative measures, a cluster of *Undaria* were found in Beach Harbor (2 km east of Sunday Cove) in 2016. A full inspection of the area and scope of the infestation is underway to determine the extent of the problem and identify new habitats that will also need to be inspected.

Analysis: Potential Applications for the Santa Barbara Channel Region

Similarities

The waters off the coast of the Channel Islands and all along the coast of California are also optimal temperatures and conditions to foster the growth and spread the invasion of *Undaria* (optimal temperature: 10-20 ºC; optimal conditions: fully saline, light availability, moderately sheltered to moderately open coasts, and positively related to nutrient concentrations; references found in Epstein & Smale, 2017). Like the Fiordland Reserve, the Channel Islands are an area of high value as their pristine environment is responsible for the millions of dollars it accrues through tourism. Reserve managers in New Zealand are concerned with the introduction of new species and have therefore implemented a plan to prevent their introduction or spread into the area. Specifically, vessels are targeted as the main vector responsible for potentially carrying marine invasive species into the area and therefore receive focused attention. Efforts to keep reserves pristine are mainly preventative, although a few aggregations of *Undaria* have been found in Fiordland but were quickly contained. California may have similar priorities to keep marine protected areas free from invasions by actively preventing the spread of *Undaria* within protected waters.

Additionally, marine pests in New Zealand tend to first appear in the most highly trafficked ports, not unlike California. Vessel movement using pathways to and from these ports to marinas on the Channel Islands is highly likely and the most probable cause for how marine pests get introduced to island waters. These similarities in vector pathways may merit a similar response to managing vectors in California.

Differences

The Fiordland Marine Reserve is situated along the mainland coast. In patrolling that area, monitoring and surveillance might be easier because there is less coastline to survey when compared the coasts of an island.

Similar to Australia, New Zealand has implemented nationwide marine pest management strategies to minimize the country wide spread. Multiple agencies are involved with these plans and help execute tasks necessary to mitigate the problem.

Opportunities and Recommendations

Fiordland management strategies serve as great templates and examples for preventative measures and rapid response actions. Adopting similar policies, such as inspections and clean vessel certifications for boats, would be beneficial for the Channel Islands or harbors along the California coast.

Aside: Thakur *et al*. (2017) found that a compound found in *Undaria*, fucoid, can be used in conjunction with a specified Melanoma treatment regimen of lapatinib, to inhibit tumor growth to 85%. This research is promoting the use of the compound to help treat patients with Melanoma. Perhaps, if we wanted to do an outreach program or create an opportunity for outside funding, we can donate harvested alga to hospitals specializing in this, in effect also getting more media attention to this invasive alga.

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Section IV

Monterey Bay National Marine Sanctuary Management Plan

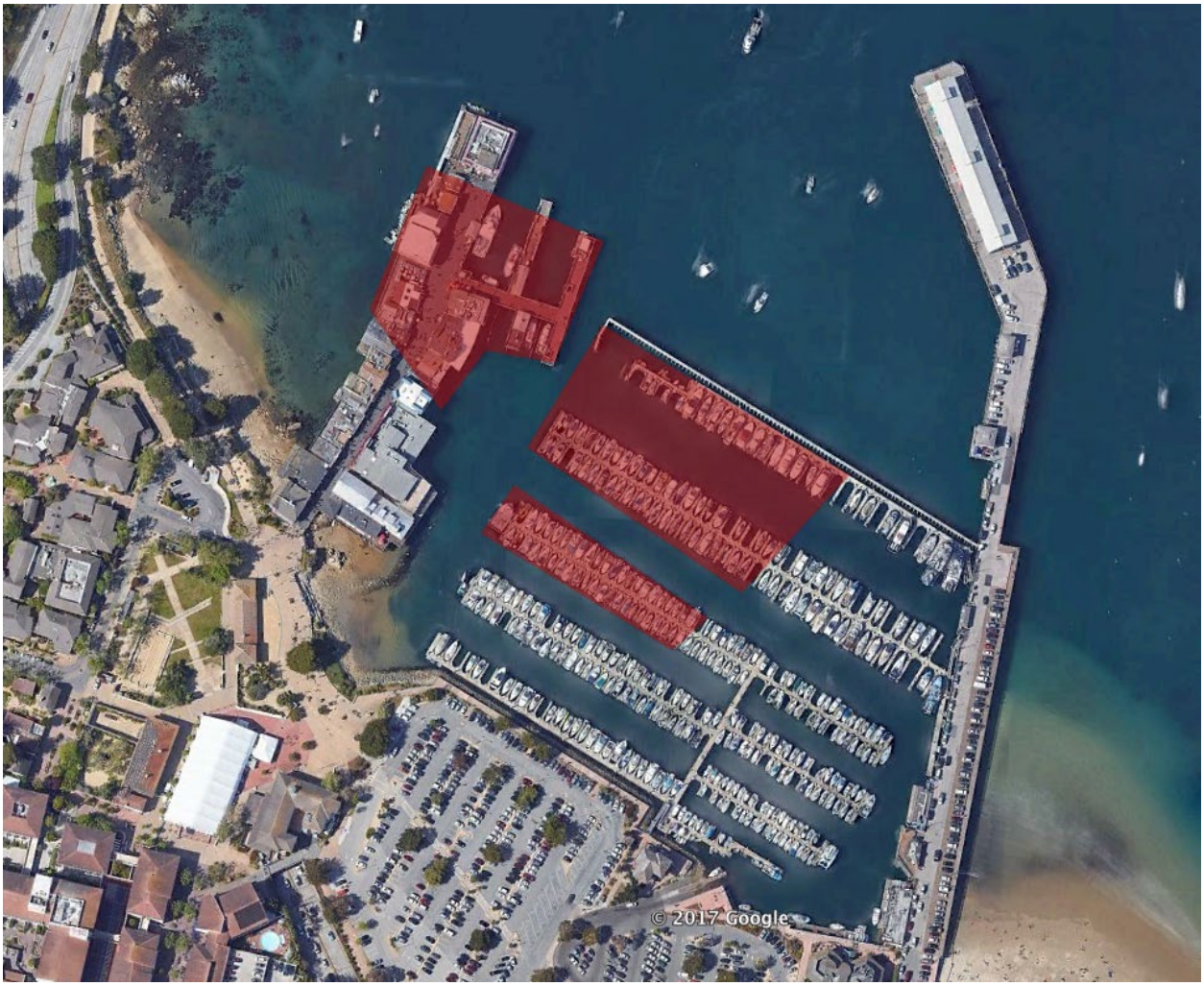


Figure 5. Red polygons symbolize the documented areas of spotted *Undaria pinnatifida* within the Monterey Harbor as of September 2016. *Source: Steve Lonhart, MBNMS.*

Introduction

Undaria pinnatifida was discovered in Monterey Bay in 2001 after it was first spotted in Long Beach and Los Angeles harbors in 2000. After its discovery, eradication and monitoring strategies ensued but efforts declined as resources and funding have been depleted. No specific sites were successful in the eradication of *Undaria*, and the species is thought not likely to be eradicated within the Bay Area.

Preventative measures were supported by some city councils such as in Emeryville City and proposals even included establishing regulations excluding certain boats from the Emeryville Marina if the boat came from *Undaria* infested waters. This regulation proposed amending Chapter 1 of Title 10 of the Emeryville Municipal Code in addition to section 1-1.03 of Chapter 1 of Title 1 and Section 1- 2.01 of Chapter 2 of Title 1. The proposed Ordinance would prohibit the berthing, anchoring, or mooring of vessels within the Emeryville Marina from waters exposed to the invasive species *Undaria pinnatifida*, unless those vessels have undertaken remedial measures. This ordinance, however, did not pass and current Emeryville Municipal Code does not reflect these changes.

Monterey Bay National Marine Sanctuary (MBNMS) at the Monterey harbor has also been invaded by *Undaria* (figure 5). Sanctuary staff collaborated with several federal, state, and local agencies along with universities to carry out its removal and management. The following agencies participated in the effort: Elkhorn Slough National Estuarine Research Reserve, University of California Santa Cruz, Moss Landing Marine Laboratories, California Department of Fish and Game, Monterey Harbor Master's Office, and City of Monterey Volunteer Services.

Management Actions

According to the MBNMS 2008 Final Management Plan's (FMP) Introduced Species Action Plan, the sanctuary staff strive to manage introduced species by developing and implementing action plans to address pathways, threats, and effective prevention/management. They gauge the severity of the threat based on four components:

1. Likelihood of the pathway leading to introductions.
2. Feasibility of the MBNMS addressing the pathway.
3. Severity of the threat posed by the pathway (or the likelihood of a species being introduced by a particular pathways).
4. Effectiveness of prevention or management efforts.

Taken from the 2008 management plan:

> The most likely pathways for the introduction of nonnative species are through ballast waters, hull fouling, and other non-ballast vessel introductions, and dispersal of adults, eggs, and larvae on currents. The MBNMS has implemented a prevention program that provides outreach to targeted audiences likely to introduce the non-native species. The scope of audiences includes the shipping industry, harbors, boaters, fishers, research, and teaching institutions, aquaculture facilities, private aquarium shops, and others. The potential audiences are then assessed to determine the most effective way to reach them, including the best message and tools to communicate the message.

The MBNMS FMP's Introduced Species Action Plan calls for the development of outreach programs promoting precautionary practices to appropriate businesses. Additionally, MBNMS intends to evaluate promoting programs that provide financial incentive for hull cleaning and doing so in areas that wash down to sewer systems. The MBNMS action plan also calls for coordination with the Coast Guard to inspect vessel discharge logs and take appropriate enforcement action if there is evidence of unauthorized ballast discharges. The MBNMS action plan also recommends coordination with the California State Lands Commission (CSLC) ballast water program.

Another important aspect to the MBNMS Introduced Species Action Plan is the expansion of their early detection programs. The plan calls for dive volunteers, area researchers, and others who spend a significant amount of time in and adjacent to the water to be targeted for receiving detection training. If species are introduced or identified, MBNMS works with partners to create a response plan by evaluating the feasibility of eradication or other management options to limit their spread.

Dr. Steve Lonhart was the principal investigator tasked to remove and/or eradicate specimens of *Undaria* found in the Bay Area. Dr. Lonhart partnered with other institutions and agencies (mentioned above) to implement a continual removal and monitoring program. MBNMS adopted Bax *et al*.'s (2001) framework of approaching control of marine invaders:

Step 1. Establish the nature and magnitude of the problem

Step 2. Set clear objectives

Step 3. Consider full range of alternatives

Step 4. Determine risks of control method

Step 5. Reduce risk

Step 6. Assess cost-benefit of control

Step 7. Monitor and evaluate the program

At the onset of the program, students from University of California Santa Cruz dove the Monterey Harbor using a stratified random design. On the docks that were surveyed, the students counted the number of *Undaria* individuals present and manually removed them. The following year, another survey was completed from the docks to see the change in location and/or movement of the species. Unfortunately, the species was more abundant throughout the marina.

Following this initial assessment and removal, eradication was deemed very unlikely in the Monterey Harbor, but the effort still focused on removal and monitoring to slow the spread. In 2011, removal and monitoring efforts ceased as funding was depleted.

Analysis: Potential Application for the Santa Barbara Channel Region

Similarities

Monterey Bay is situated along the California coast with access to similar resources, partners, and agencies. The MBNMS must also comply with Sanctuary regulations (Code of Federal Regulations, Title 15, Part 922, National Marine Sanctuary Program Regulations), specifically, regulation §922.132(12) (mentioned earlier), to maintain their native marine ecosystems.

Therefore, MBNMS, like CINMS has an added responsibility to manage and/or eradicate introduced species. Like Australia and New Zealand, MBNMS needs the support of multiple agencies across multiple levels to contain the spread.

Differences

The *Undaria* populations found and managed in Monterey are constrained to marinas and adjacent areas, unlike the *Undaria* found in the open-coast benthic habitat off the Anacapa and Catalina Islands. Additionally, waters in this region are turbid and projects for removal of sporophytes were sometimes unsuccessful because visibility was low.

MBNMS began eradication and monitoring efforts shortly after *Undaria* was found in the area. Now, CINMS and partners have the opportunity to learn and implement MBNMS's best removal strategies, if applicable. Some of these removal strategies include cutting the specimen below the meristem to ensure the death of the individual and then bag the sporophyte to dispose of it.

Opportunities and Recommendations

Monterey Bay National Marine Sanctuary (MBNMS) first sought help from university students to dive and locate where the alga was growing and record the location. The divers removed the sporophytes and compiled the aforementioned data. The following year, a dockside assessment reviewed the impacts of the removal effort. CINMS could also employ this method by organizing students from the local universities to aid in their initial assessment of the locations and spread of *Undaria*.

Additionally, programs such as Kelp Watch, developed by the Smithsonian Environmental Research Center, provided an email and entry webpage for recording *Undaria* sightings. Kelp Watch reached out to agencies responsible for responding to sightings within their jurisdiction along the coast. Kelp Watch's goal was to assess the situation, manage, and observe the spread of the alga. CINMS has already joined with others in helping to promote a program similar to this on the Marine Invasives webpage (marineinvasives.org), which provides information to help divers, boaters and others recognize invasive algae and an online tool for submitting sightings information. Future opportunities lie in the implementation of a single site to manage the all sightings and a web of agencies along the coast to facilitating response actions.

The *Undaria* Removal Project in Monterey Bay provides recommendations to improve the facilitation of *Undaria* removal and could be used to draw upon for the Santa Barbara region.

Key Contacts

MBNMS SIMoN Senior Scientist, Steve Lonhart

Smithsonian Environmental Research Center, Chela Zabin

References

Bax, N. Carlton, J.T. Mathews-Amos, A. Haedrich, R.L. Howarth, F.G., Purcell, J.E. Rieser, A. and Gray, A. (2001) The control of biological invasions in the world's oceans. *Conservation Biology,* 15:1234-1246.

Lonhart, S. (2009) Final Report to NOAA Community-Based Restoration Program Monterey Bay *Undaria* Removal Project.

Monterey Bay National Marine Sanctuary. Final Management Plan-Section III-Ecosystem Protection. 2008.

Section V

Quagga and Zebra Mussel Action Plan

Zebra mussel (*Dreissena polymorpha)*
Quagga mussel (*Dreissena bugensis)*
Credit: Invasives Species Council of BC

Introduction

The quagga-zebra mussel invasion is one of the most devastating invasions in North American freshwater systems. Once established, these mussels can clog water intake and delivery pipes, infest hydropower infrastructure, foul boats, pilings, and recreational beaches, all causing negative economic impact. The establishment and spread of these mussels also creates competition with native mussels, in turn leading to disruption of food webs and bioaccumulation of toxins.

The infestation has continued to spread and can now be found in reservoirs in Southern and Central California. Due to their extensive negative economic and ecologic impact, many states have joined together to implement programs to help prevent the spread of the mussels. One of these methods was creating a watercraft inspection program for vessels entering and exiting infested and un-infested waters in water bodies throughout the west. Some inspection points within the program require vessels to have a signed and stamped vessel screening permit that is good for 21 days before it is to be renewed.

Management Actions

The Quagga-Zebra Mussel Action Plan for Western U.S. Waters (QZAP) was developed by the Western Regional Panel (WRP). The WRP consists of 19 western states, federal agencies, tribes, and other invasive species stakeholders. The primary coordinating body is the 100th Meridian Initiative which engages various federal and state agencies, tribes, and local groups. The action plan outlines the efforts needed to stop this highly invasive species and is estimated to cost around $1.2 billion per year. The highest priority actions in the action plan include:

Increasing capacity to address invasive mussels

- State and interstate Aquatic Nuisance Species Task Force management plan funding and QZAP implementation.

Prevention

- Implement mandatory inspection and decontamination at infested waters.
- Continue the development of effective watercraft inspection and decontamination protocols and standards.
- Develop standard and effective equipment inspection and decontamination protocols.
- Adopt standard watercraft and equipment inspection and decontamination protocols in Western states.
- Establish and implement strong, consistent law enforcement programs in each western state.
- Develop a standardized model and strategy for risk assessment model for water bodies.

Early Detection Monitoring

- Expand early-detection monitoring programs to all western water jurisdictions.
- Develop standard field protocols for early-detection monitoring.

Rapid Response

- Create and maintain a rapid response fund.
- Finalize rapid response notification database.

Containment of Management of Existing Populations

- Develop tools and best management practices for preventing and minimizing mussel movement and settlement within water distribution systems and other infrastructure.

Outreach and Education

- Adopt consistent outreach messaging and enhance coordination of efforts.

One of the most cost-effective and ecologically protective approaches to managing this species is through the use of preventative action. From the years 1993-1999 the estimated cost to several different industries, businesses, and facilities together was over $8 billion. Research and cost benefit analyses have shown preventative measures will cost less than what it would to repair damaged systems. For this reason, many of the local, state, and federal owners of unaffected reservoirs have implemented watercraft inspection programs which vary state by state, waterbody by waterbody. Funding for these programs also vary by waterbody. Some inspection points and permits are funded on each level: local, state, and federal. In each of the US Fish & Wildlife Service Regions there is an Aquatic Nuisance Species State Coordinator who may help coordinate participation and funding for management programs.

In California, several funders are available for quagga-zebra mussel prevention, control, or eradication programs. These funders include local, state, and national government agencies. These are found in a document referenced in the California Department of Fish & Wildlife Quagga Mussels webpage.

Additionally, USFWS Regional AIS Coordinators have developed materials for outreach and awareness campaigns. These materials include: informational websites, workshops, traveling displays, exhibits, pamphlets, AIS identification cards, fact sheets (in multiple languages), and videos. Outreach and education has been developed in the west in an effort to standardize the message shared with the public. Each individual state/waterbody implements their own outreach/education.

Analysis: Potential Application for the Santa Barbara Channel Region

Similarities

Like zebra and quagga mussels, *Undaria* has the potential to invade other areas once introduced; these species foul easily on hard substrates and can tolerate a wide range of environmental factors. While the *Undaria* and mussel invasions differ in many ways, there is potential to apply preventative strategies used for invasive mussels to the management of *Undaria*. In both of these cases, vectors for spread is the primary concern. Points of inspection (whether on land or in the water) and other vector regulations are imperative to prevent the spread into unaffected areas.

Differences

The quagga-zebra mussel invasion is a widespread problem across the nation; its spread is hard to manage because these species are prolific, small, and foul easily on boats. A national plan as well as state plans exist to try to prevent further spread. Conversely, *Undaria* is a problem local to central and southern California. Additionally, mussel checkpoints are typically performed on land before the boats enter the water and are thoroughly inspected everywhere (including water gear and flotation devices). This is a limitation for the Channel Islands as boaters traveling in the reserves normally never take the boat out of the water unless it is back at their own dock where Channel Island inspectors cannot conduct their own inspections. If inspections were to take place

on the islands, most inspections would consist of checking if the vessel has their clean vessel pass (if applicable) or through visually observing fouling on hulls.

Opportunities and Recommendations

Prevention: The Director of the Fish and Wildlife Service, the Secretary of Transportation and the Under Secretary of Commerce for Oceans and Atmosphere are authorized to issue rules and regulations to implement the Aquatic Nuisance Species Program at the recommendation of the Aquatic Nuisance Species Task Force (110 Stat. 4085,4087,4091). The most imperative management strategy to employ is management of vectors because this is the most likely mechanism of spread. This could take the form of a vessel screening permit system to help prevent the spread of *Undaria* by vessels entering harbors or visiting areas that are not yet invaded by *Undaria*.

Education and Outreach: Through the USFWS AIS Regional Coordinator, we can incorporate messaging about *Undaria* into his/her national distribution and outreach efforts. The USFWS AIS Regional Coordinator can also be responsible for connecting multiple agencies and stakeholders to each other to create a unified front against the spread of *Undaria* to unaffected harbors and habitats.

Contacts

Regional AIS Coordinator for the Pacific Region, Linda Beck

Acting Regional AIS Coordinator for the California and Nevada Region, Louanne McMartin

References

Western Regional Panel on Aquatic Nuisance Species. (2010) Quagga-Zebra Mussel Action Plan for Western U.S. Waters. *Submitted to the Aquatic Nuisance Species Task Force*.

APPENDIX A

FIORDLAND
CLEAN VESSEL PASS

YOUR DETAILS

Name: _____

If you are a representative for this vessel – please provide the name of person or organisation you represent:

_____

Email address: _____

Postal address: _____

_____

_____

Phone no.: _____

VESSEL DETAILS (**ONE** Clean Vessel Pass required **PER VESSEL.** Valid 12 months.)

1. **Vessel name** – if your vessel is unnamed please enter **NONE:**

   _____

2. **Vessel MNZ/MSA number or call sign:**

   _____

3. **Vessel type** – select **ONE** of the following :

   - ☐ Charter vessel
   - ☐ Fishing vessel
   - ☐ Kayak/canoe
   - ☐ Military
   - ☐ Person carrier
   - ☐ Recreational powerboat
   - ☐ Recreational yacht
   - ☐ Research vessel
   - ☐ Service vessel
   - ☐ Special purpose vessel
   - ☐ Other (please specify):

   _____

4. **Vessel length** – select **ONE** of the following :

   - ☐ 1 - 10 metres
   - ☐ 10 - 15 metres
   - ☐ 15 metres +

5. **Closest home port** – select **ONE** of the following :

   - ☐ No home port (e.g. trailer boat/kayak)
   - ☐ Fiordland based
   - ☐ Stewart Island
   - ☐ Southland
   - ☐ Otago
   - ☐ Westland
   - ☐ Canterbury
   - ☐ Nelson/Marlborough
   - ☐ Wellington
   - ☐ Hawkes Bay
   - ☐ Taranaki
   - ☐ Gisborne
   - ☐ Bay of Plenty
   - ☐ Waikato
   - ☐ Auckland
   - ☐ Northland
   - ☐ International (please specify):

   What country is regarded as your home port?

   _____

   What country will be your last port of call before entering New Zealand?

   _____

environment SOUTHLAND
REGIONAL COUNCIL
Te Taiao Tonga

FIORDLAND TRIP INTENTION DETAILS

6. **Tick ALL the ports you are likely to visit over the next 12 months**

- ☐ Stewart Island
- ☐ Southland
- ☐ Fiordland
- ☐ Otago
- ☐ Westland
- ☐ Canterbury
- ☐ Nelson/Marlborough
- ☐ Wellington
- ☐ Hawkes Bay
- ☐ Taranaki
- ☐ Gisborne
- ☐ Bay of Plenty
- ☐ Waikato
- ☐ Auckland
- ☐ Northland
- ☐ International
- ☐ Other
- ☐ None

7. **Trip intention** (select **ALL** that apply over the next 12 months)

- ☐ Commercial tourism
- ☐ Commercial fishing
- ☐ Charter
- ☐ Recreational
- ☐ Other (please specify)

_____

8. **Select where your vessel will reside MOST of the time in Fiordland**

- ☐ Multiple locations - northern fiords
- ☐ Multiple locations - southern fiords
- ☐ Multiple locations - throughout Fiordland
- ☐ Big Bay
- ☐ Milford Sound
- ☐ Poison Bay
- ☐ Sutherland Sound
- ☐ Bligh Sound
- ☐ George Sound
- ☐ Caswell Sound
- ☐ Charles Sound
- ☐ Nancy Sound
- ☐ Thompson Sound
- ☐ Doubtful Sound
- ☐ Dagg Sound
- ☐ Breaksea Sound
- ☐ Dusky Sound
- ☐ Chalky Inlet
- ☐ Preservation Inlet

9. **Select the months you are likely to visit Fiordland within the next 12 months**

- ☐ All Months
- ☐ January
- ☐ February
- ☐ March
- ☐ April
- ☐ May
- ☐ June
- ☐ July
- ☐ August
- ☐ September
- ☐ October
- ☐ November
- ☐ December

10. **Select the expected period the vessel will reside in Fiordland over the next 12 months**

- ☐ Day trip or short stay (up to 1 month)
- ☐ Medium stay (1 to 3 months)
- ☐ Long stay (over 3 months)

BIOSECURITY DETAILS

11. **Where was the hull of the vessel (including niche areas) last cleaned?** (specifiy date below).

- ☐ Stewart Island
- ☐ Southland
- ☐ Fiordland
- ☐ Otago
- ☐ Westland
- ☐ Canterbury
- ☐ Nelson/Marlborough
- ☐ Wellington
- ☐ Hawkes Bay
- ☐ Taranaki
- ☐ Gisborne
- ☐ Bay of Plenty
- ☐ Waikato
- ☐ Auckland
- ☐ Northland
- ☐ International
- ☐ Never

Date vessel last cleaned : _____

12. **Frequency that the vessel is antifouled or surveyed:**

- ☐ Annually
- ☐ Every 2 years
- ☐ Every 3 years
- ☐ As required
- ☐ Never

Date vessel last antifouled: _____

13. **Has the gear associated with the vessel been in seawater outside of Fiordland in the last 12 months?** (Please ensure gear is free of marine debris, dry if possible, and preferably treated.)

- ☐ Yes
- ☐ No

14. **Does the vessel have any compartments that retain residual seawater such as live wells?** (Please ensure water is removed or treated prior to every visit to Fiordland)

- ☐ Yes
- ☐ No

GENERAL DETAILS

15. **We may occasionally send you information in relation to the Fiordland Marine Regional Pathway Management Plan or other issues which may be of interest.** Please select below if you wish to receive this information.

- ☐ Yes – I wish to receive further information

16. **A clean vessel pass will be emailed to you once your details are processed.** Please select if you would like a waterproof copy to be sent to the address provided.

- ☐ Yes – I would like a waterproof copy.

DECLARATION

☐ I declare (as the representative for this vessel and on behalf of those who will operate it over the next 12 months) that I have read and understood the clean hull standard, clean gear standard and residual seawater standard as at the date of this declaration and that

_____
(insert vessel name)

will comply with those standards on every entry into the area within one nautical mile of the landward margin of the Fiordland Marine Area for the duration of the Clean Vessel Pass.

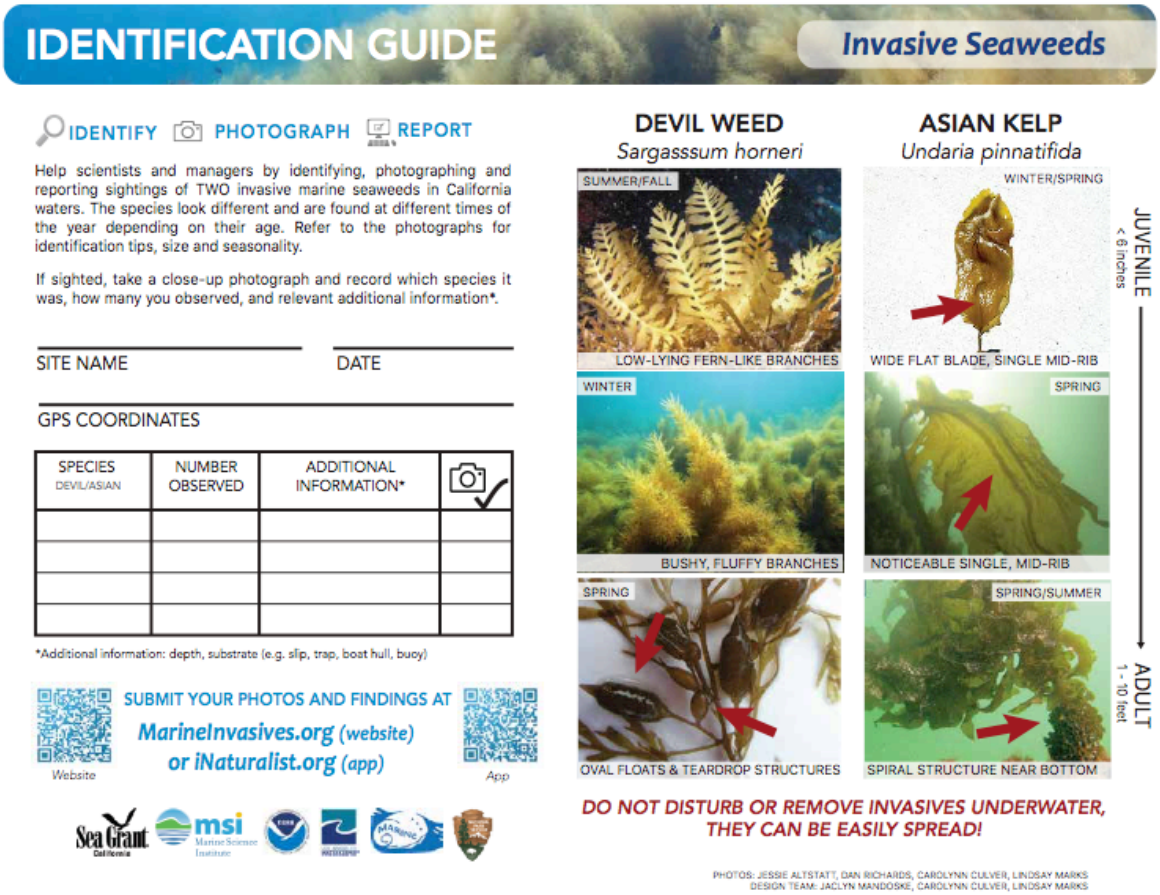
_____ _____
(signature) (date)

PLEASE RETURN TO ENVIRONMENT SOUTHLAND
Private Bag 90116, Invercargill 9840
Cnr North Rd & Price St, Waikiwi, Invercargill
Fax 03 211 5252
Email service@es.govt.nz

0800 76 88 45 or 03 211 5115 | service@es.govt.nz | www.es.govt.nz


Clean Vessel Pass Area
Fiordland Marine Area
Big Bay
Milford Sound
Poison Bay
Sutherland Sound
Bligh Sound
George Sound
Caswell Sound
Charles Sound
Nancy Sound
Thompson Sound
Doubtful Sound
Dagg Sound
Breaksea Sound
Dusky Sound
Chalky Inlet
Preservation Inlet
FIORDLAND
NATIONAL
PARK
The Fiordland Marine Regional Pathway Management Plan is developed and implemented by a partnership group including:
environment SOUTHLAND
Department of Conservation
Ministry for Primary Industries
Te Rūnanga o NGĀI TAHU
Fiordland Marine Guardians

APPENDIX B

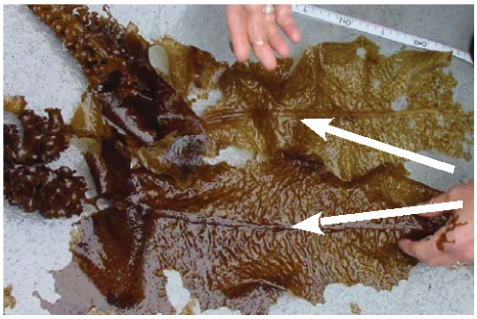

IDENTIFICATION GUIDE
Invasive Seaweeds
IDENTIFY PHOTOGRAPH REPORT
Help scientists and managers by identifying, photographing and reporting sightings of TWO invasive marine seaweeds in California waters. The species look different and are found at different times of the year depending on their age. Refer to the photographs for identification tips, size and seasonality.
If sighted, take a close-up photograph and record which species it was, how many you observed, and relevant additional information*.
SITE NAME
DATE
GPS COORDINATES
SPECIES DEVIL/ASIAN
NUMBER OBSERVED
ADDITIONAL INFORMATION*
*Additional information: depth, substrate (e.g. slip, trap, boat hull, buoy)
SUBMIT YOUR PHOTOS AND FINDINGS AT
MarineInvasives.org (website)
or iNaturalist.org (app)
Website
App
DEVIL WEED
Sargasssum horneri
ASIAN KELP
Undaria pinnatifida
SUMMER/FALL
LOW-LYING FERN-LIKE BRANCHES
WINTER/SPRING
WIDE FLAT BLADE, SINGLE MID-RIB
JUVENILE
< 6 inches
WINTER
BUSHY, FLUFFY BRANCHES
SPRING
NOTICEABLE SINGLE, MID-RIB
SPRING
OVAL FLOATS & TEARDROP STRUCTURES
SPRING/SUMMER
SPIRAL STRUCTURE NEAR BOTTOM
ADULT
1 - 10 feet
DO NOT DISTURB OR REMOVE INVASIVES UNDERWATER,
THEY CAN BE EASILY SPREAD!
PHOTOS: JESSIE ALTSTATT, DAN RICHARDS, CAROLYNN CULVER, LINDSAY MARKS
DESIGN TEAM: JACLYN MANDOSKE, CAROLYNN CULVER, LINDSAY MARKS

APPENDIX C

ATTENTION ISLAND DIVERS

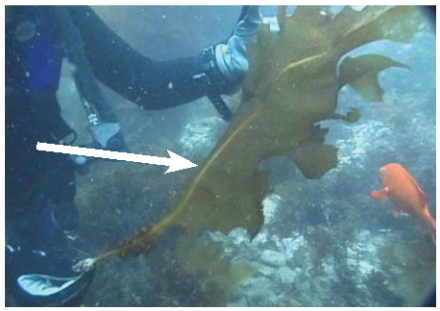
Help LOOK FOR and REPORT SIGHTINGS of this kelp!

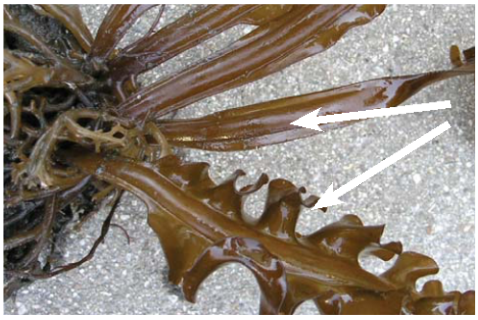
The invasive kelp *Undaria pinnatifida* has recently been found on rocky reefs on the north side of **Anacapa Island** and it may be elsewhere.



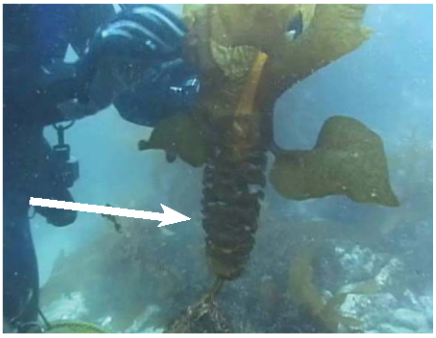
ID TIPS:

SINGLE FLAT MID-RIB





FLAT TO VERY RUFFLED NEAR BOTTOM (DEPENDING ON AGE)



REPORT LOCATION (GPS) DEPTH NUMBER SEEN PHOTOGRAPH (if possible)

to ***MarineInvasives.org***

Please do not touch or remove this kelp because it can be easily spread!

Sea Grant California

Your observations are important and may help guide further action and response

APPENDIX D: Table Summary of Preliminary Action Items

Title of Action	Estimated Funding Cost	Implementation Effort
Vector Management	Unknown	Difficult
Removal	High	Difficult
Continual Monitoring	Moderate	Manageable/Difficult
Education and Outreach	Low	Manageable
Research	Moderate	Manageable