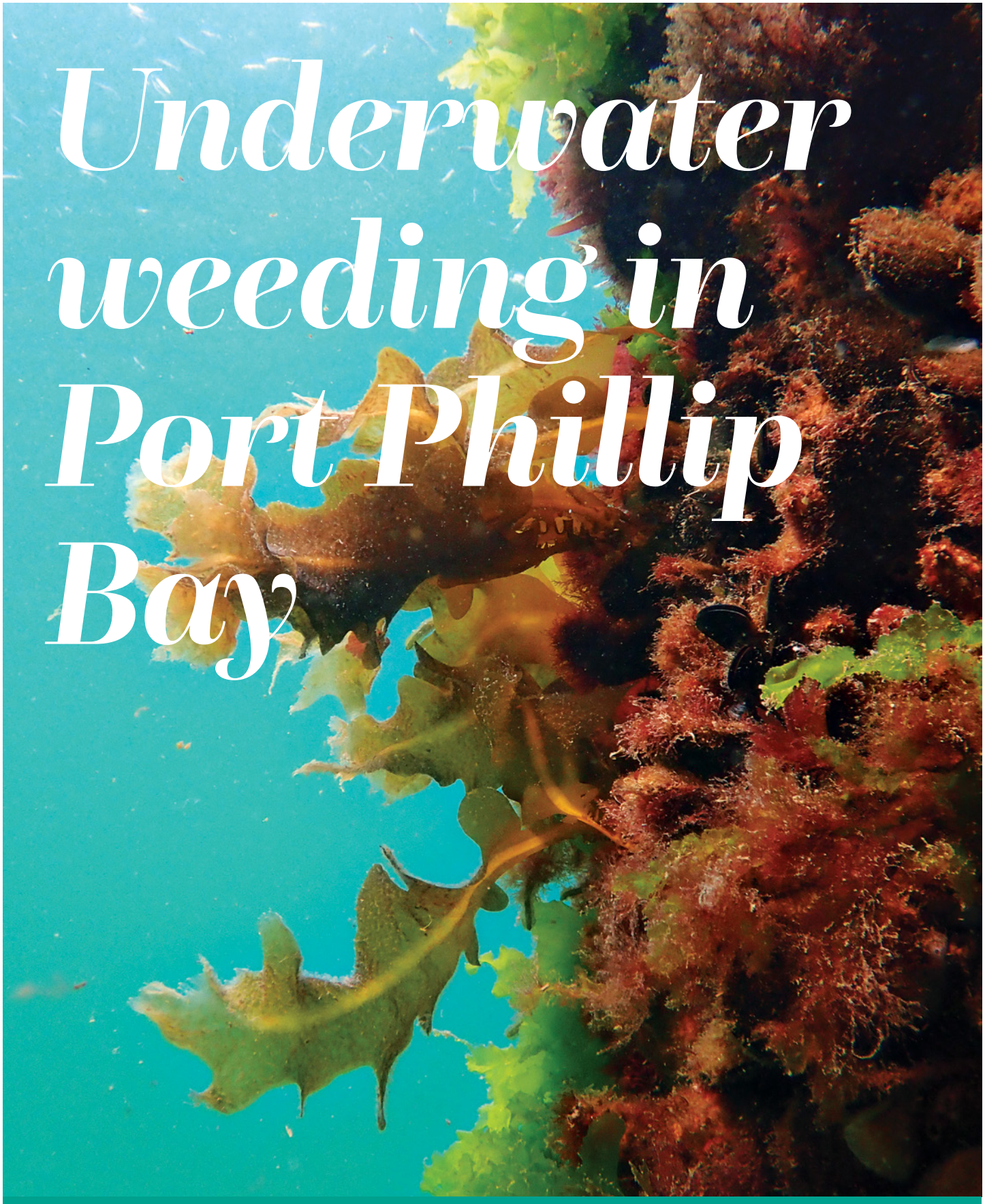
Underwater weeding in Port Phillip Bay



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Community led removal of the introduced algae *Undaria pinnatifida*

Acknowledgement

We are blessed in Victoria with a passionate marine community that will do all it can to protect and promote life under the surface. The following people went above and beyond in helping with this project – Paul Sorensen, Jane Bowman, Liz Harper, Corinne Telford, Ting Ting Lee, Morgan Kurrajong, Julianne Stewart, Anne Kyle, Fam Charko, Sabrina Trocini, Ivan Lee and Nicky Filby. An extra special thanks to Jacqui Pocklington, Richard Stafford-Bell and Trevor Graham for their numerous improvements to the final report.

***Underwater weeding in Port Phillip Bay: Community led removal of the introduced algae* Undaria pinnatifida**

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VICTORIAN NATIONAL PARKS ASSOCIATION
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We've led the creation, oversight and defence of Victoria's natural estate for over 70 years.

Port Phillip Bay/Nerm is part of the unceded traditional lands and waters of the Bunurong, Wadawurrung and Wurundjeri People.

VNPA acknowledges the many First Peoples of the area now known as Victoria, honours their continuing connection to, and caring for, Country, and supports Traditional Owner joint-management of parks and public land and waters for conservation of natural and cultural heritage. We offer our respect to Elders past and present.

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Executive summary

Port Phillip Bay/Nerm* is home to over 160 invasive marine animals and algae, including the well-established large algae *Undaria pinnatifida* (hereafter referred to as Undaria), which is widespread at marine habitats and popular dive sites. While it is common, many local divers remain unaware of Undaria and the risks invasive animals and algae pose to marine habitats in the bay. This project offered community members a practical, hands-on opportunity to actively participate in marine weed removal efforts to improve their local marine environment.

The Underwater Weeding Project ran from April 2022 to September 2024, engaging the Port Phillip Bay marine community in identifying and removing Undaria at their local dive sites. This initiative achieved high levels of community participation, with divers removing invasive species while fostering stewardship for the local marine environment. The concurrent removal of other pests, such as Northern Pacific Seastars, and marine debris highlighted the project's environmental impact.

Key impacts

Environmental impact: A total of 11,767 Undaria were removed from 12 sites throughout Port Phillip Bay.

Community impact: 422 participants were involved in hands on action to remove an invasive algae. Additionally, participants fielded questions and informed 356 members of the public of the work they were undertaking and informed them about marine invasive animals and algae in Port Phillip Bay. The project bolstered community education on invasive species, enhanced local biodiversity stewardship, and inspired broader engagement in marine conservation.

Key achievements

Community engagement: Divers and snorkellers were trained to identify and safely remove Undaria. This proactive engagement fostered a strong sense of environmental responsibility within the diving community and increased public awareness of marine pests.

Adaptable event schedule: Removal events were strategically aligned with Undaria's lifecycle, targeting peak growth seasons while accommodating weather challenges and diver availability. The project extended events beyond the initially planned Winter–Autumn schedule for maximum impact.

Accurate and effective training: A structured training program minimised non-target algae removal, with mentorship pairing new participants with experienced divers. The use of visual aids and pre-dive seminars ensured effective learning and execution.

Sustainable practices: Removed Undaria was composted, repurposed for food, or utilised in other sustainable ways, avoiding landfill disposal.

Challenges and lessons learned

Weather dependency: Inclement weather necessitated flexibility in event scheduling while balancing the need for consistency.

Site access restrictions: Collaboration with Parks Victoria (PV) ensured safe and permitted access to key removal sites, improving operational efficiency.

Refinement of techniques: Initial methods for sporophyll removal were adjusted to increase efficiency and reduce environmental impact, allowing large-scale removal at infested sites.

Ongoing and future plans

- Many groups have incorporated Undaria removal into their annual dive calendars, ensuring sustained efforts.
- A dedicated portal on the Atlas of Living Australia enables data tracking and fosters broader collaboration.
- Partnerships with businesses like Southern Seagreens explore whether Undaria removal supports native species' regrowth and develops sustainable uses for the seaweed.
- Public involvement in removal and monitoring efforts could expand, increasing the capacity for pest control inside and outside marine protected areas.
- Further research is needed to evaluate the long-term ecological benefits of Undaria removal. Collaborations between researchers and community groups could investigate whether removal promotes the recovery of native algal species over a 5–10 year period.
- Scaling up kelp restoration trials, such as those targeting Golden Kelp in Port Phillip Bay, presents an exciting opportunity. Community involvement in removing Undaria from restoration areas and maintaining these sites could significantly support these initiatives.

This initiative demonstrates how community-led conservation projects can address complex environmental challenges while fostering education, collaboration, and sustainable practices. Building on these successes, continued research and enhanced community engagement will be vital in protecting Port Phillip Bay's marine ecosystems.

Ocean Divers with their Undaria haul, Brighton *Liz Harper*

*Nerm is the traditional name for Port Phillip Bay in the Boon Wurrung language of the Bunurong People

Meeting the locals at Brighton *Kade Mills*

UNDERWATER WEEDING IN PORT PHILLIP BAY VNPA REEFWATCH

Introduction

Port Phillip Bay is home to over 160 invasive marine species, making it a hotspot for marine biodiversity threats (State of the Marine & Coastal Environment, 2021). Among these, Undaria has been present for many years and is now considered established. DEECA's current management strategies are focused on limiting its spread beyond Port Phillip Bay into new areas. This approach reflects an acceptance that many invasive species are now permanent fixtures in the bay, shifting the focus of public education toward high-risk recreational activities, such as boating, which can inadvertently spread pests outside the bay.

However, this focus has led to a decline in ongoing education for recreational divers about invasive marine animals and algae. Many divers remain unaware of the existence and ecological threats posed by these species within Port Phillip Bay (pers. obs.). Efforts to manage Undaria have primarily focused on preventing its spread into sheltered waters beyond Port Phillip Bay. However, there is growing concern about its potential to gradually extend beyond Port Phillip Heads and invade previously unaffected open coastal areas.

PV has initiated removal efforts within the Port Phillip Heads Marine National Park at Popes Eye. These efforts required significant resources but continue to have reduce Undaria numbers utilising a simple, effective method for removing mature Undaria. Monitoring and regular weeding continue to maintain the site.

The success of this project prompted the idea of involving the public in underwater weeding. By training recreational divers and snorkellers in the identification and removal of Undaria, this initiative would expand the capacity for controlling its spread both inside and outside marine protected areas (MPA). At the same time, it would raise awareness of this often overlooked environmental issue.

Additionally, Undaria has commercial value as a high-quality seaweed harvested for culinary use[1], liquid fertiliser[2] and for extracting Fucoidan for health benefits[3]. There is growing interest in seaweed as a sustainable food source, with proponents suggesting it could reduce the demand for terrestrial crops (Spillias et al., 2023). By engaging the community in its removal and educating them on its potential uses, this project could further connect people to an edible, garden-friendly resource, while helping to protect marine habitats.

Objectives of the Underwater Weeding project

This project aimed to train divers/snorkellers in the identification and removal of Undaria at sites throughout Port Phillip Bay. Expected outcomes included:

- An underwater community engaged, educated and trained to safely remove Undaria in Port Phillip Bay.
- Increased community knowledge of and engagement with marine pest species in Port Phillip Bay.
- Increased capacity built in existing marine community groups working inside and outside of MPAs, in pest species

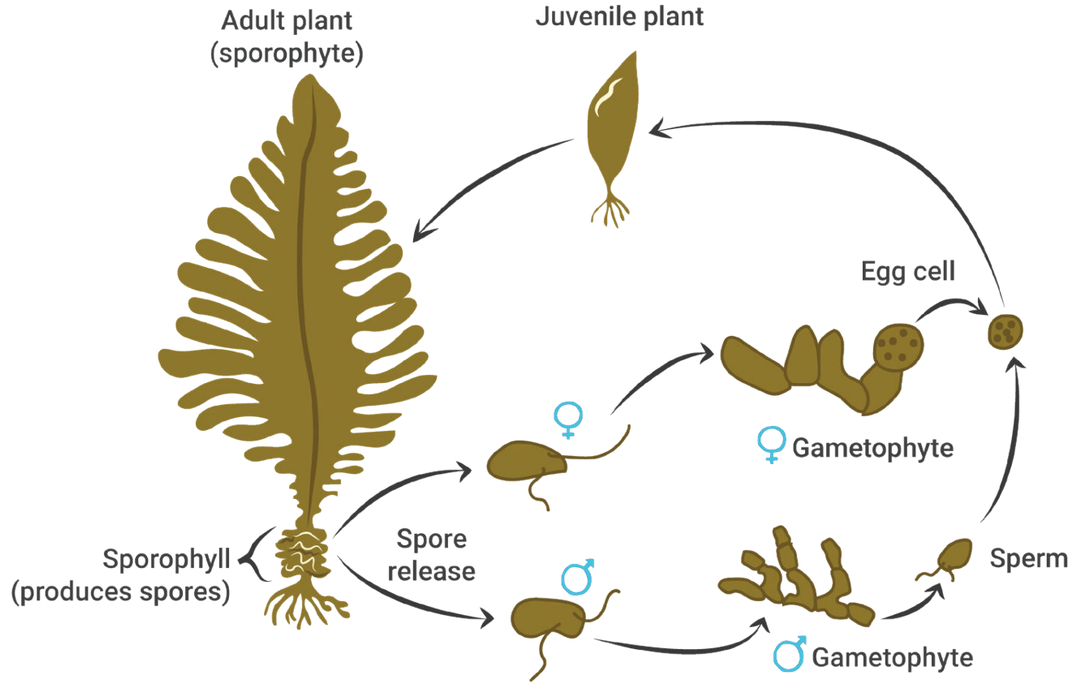


Fig 1: Life cycle of Undaria *Source: Sinner, J, Forrest, B & Taylor, M (2000) A Strategy for Managing the Asian Kelp Undaria: Final Report, Ministry of Fisheries NZ*

Undaria with developed sporophylls *Kade Mills*

knowledge, early detection and removal practices.

- Increased practical protection strategies for marine assets in the Bay.
- Increased collaborations between stakeholders for marine asset protection, most notably community groups, not-for-profits, local Councils, State Government, agencies and businesses.

The story of Undaria

Undaria is a large brown seaweed native to northeast Asia and the far east of Russia. It is the second most economically significant brown alga globally, after *Laminaria japonica*, with over 2 million tonnes cultivated annually in Japan, Korea, and China. Although traditionally a luxury food in Japan and Korea, Undaria's consumption is rising in China.

Undaria has spread to all continents except Africa and Antarctica, primarily through shipping and aquaculture escape. It was first introduced to Australia in Tasmania in the late 1980s, followed by its appearance in Victoria's Port Phillip Bay in 1996. Currently, it is widespread throughout the bay. The International Union for Conservation of Nature (IUCN) lists Undaria as one of the world's 100 worst invasive species. It is also considered a nationally significant marine pest in Australia.

Life cycle of Undaria

Undaria has a high reproductive output, fast growth, early and rapid maturation along with an ability to delay development during unfavourable conditions making it a highly successful invader (South et al., 2017). The mature Undaria that divers come across can be broken down into three main parts

1. **The blade:** this leaf-like structure absorbs sunlight and oxygen for photosynthesis to produce energy for the algae to grow.
2. **The sporophyll:** this wavy structure at the base of the algae produces spores which are then released into the water
3. **The holdfast:** this bundle of 'spaghetti' at the base of the algae anchors it to the substrate

Undaria can grow up to 3 metres and is capable of releasing up to 700,000,000 microscopic spores over the lifetime of the sporophyll (Schiel & Thompson, 2012). The male and female spores are released into the water column before settling on the seabed where they develop into microscopic male or female gametophytes. The gametophytes develop and when mature the male will release sperm that moves through the water to fertilise the female in situ where it will start to grow into a mature algae (Schiel & Thompson, 2012). These microscopic life stages have been observed to persist for up to 2.5 years (Hewitt et al., 2005).

Undaria in Victoria

Undaria was introduced into Victoria's Port Phillip Bay via Tasmania. It was first discovered at Point Wilson in July 1996 (Campbell & Burridge, 1998). Since then, it has become widespread, mostly growing on various hard substrates, including reefs, pylons, and boat hulls. It was discovered in Apollo Bay Harbour in 2009, where it remains contained. Additionally, it has been detected in Portland Harbour and at Port Welshpool.

Impact of Undaria on native species

The ecological impacts of Undaria vary widely, with studies providing differing results. In some environments, Undaria has been shown to significantly compete with native and algae for essential resources such as space, light, and nutrients, leading to notable reductions in the richness and biomass of native macroalgal species (Valentine & Johnson, 2003). This invasive behaviour has raised concerns about the displacement of native kelps and the overall biodiversity of affected ecosystems.

However, in other regions, Undaria is considered a less aggressive invader. Some studies suggest that it is a poor competitor and tends to establish primarily in areas already disturbed or devoid of native large algae, known as macroalgae. In such contexts, it has minimal ecological impact on native species (Floc'h et al., 1996; Valentine & Johnson, 2005; Brown & Lamare, 1994).

In Port Phillip Bay (Crockett et al., 2017) found that grazing by native sea urchins influenced native macroalgae more than Undaria, also concluding that intact native algal habitats effectively prevent Undaria infestation. This has been supported by other studies from Australia and New Zealand (Valentine & Johnson 2003; Carnell & Keough, 2014 and South et al., 2016).

UNDERWATER WEEDING IN PORT PHILLIP BAY VNPA REEFWATCH

Project information

Recruitment and training of participants

At the beginning of the project, local dive businesses and groups were approached and invited to contribute to the program's design. This collaborative approach fostered a sense of ownership among stakeholders, encouraging long-term engagement. Additionally, by involving these businesses, all participants were covered by the businesses' insurance policies, and the project benefited from having experienced, trained divers and snorkellers as team leaders, who were capable of safely leading removal events.

Dive businesses and many of the groups allocated qualified staff to act as team leaders and committed to setting a regular monthly schedule for Undaria removal activities (e.g. first Saturday of each month). These events were integrated into the social calendars of the businesses and groups, ensuring consistent, ongoing participation and support from trained personnel. A few of the smaller groups ran flexible events to target key areas and work around the weather.

Participants were primarily recruited by the dive businesses and groups, a method that allowed them to work with divers they were already familiar with. This not only strengthened relationships within the diving community but also engaged participants in meaningful conservation work that directly contributed to the protection of their local dive sites.

Community members were trained in workshops, with mentoring and with instruction sheets. Training for participants focused on two key skills:

1. Differentiating between the invasive Undaria and the native Golden Kelp *(Ecklonia radiata)*.
2. Learning how to remove Undaria in a way that minimised the release of spores into the water column.

To begin the training process, samples of Undaria were collected and presented to team leaders and participants during a workshop held one or two days before their first removal event. During the seminar, they were trained to identify Undaria and properly remove it with minimal spore release using live samples.

Each team leader was also provided with two laminated booklets: one for distinguishing Undaria from Golden Kelp (Appendix 1), and the other for demonstrating the correct removal techniques (Appendix 2).

For participants who arrived on removal days without prior training, the laminated guides were used as teaching tools, and they were paired with trained divers. This hands-on mentorship allowed them to observe and practice identifying and removing Undaria until they could do so independently.

Community education

Two instructional booklets: one to help differentiate between Undaria and the native Golden Kelp, and the other to demonstrate the correct method for removing mature Undaria while minimising spore release (both of these guides are included with this report). These resources were created so team leaders had the necessary tools to educate participants, even those who arrived on the day without prior knowledge of how to identify or remove Undaria.

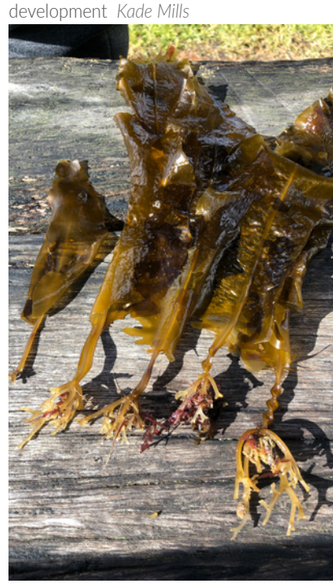
During initial site inspections and removal dives, it quickly became clear that participants were eager to learn more about Undaria, particularly its life cycle, how it was introduced, and the potential benefits of 'underwater weeding.' This interest led to the creation of a more comprehensive eight-page guide (Appendix 3), which provided detailed answers to these questions and more. An additional benefit of this guide was that it deepened team leaders' and participants' understanding of the importance of their efforts, giving them a clearer sense of purpose and responsibility in the removal process.

The guide also empowered participants to engage with the public, helping to spread awareness about marine pests and the issues surrounding Undaria. As a result, the broader community became more informed and supportive of the control efforts. Feedback from the public was overwhelmingly positive, with many expressing gratitude for the work being done by the volunteers. This ongoing support and encouragement from the community will be crucial in ensuring that these efforts continue into the future, reinforcing the value of public involvement in environmental conservation.

Removal and disposal of marine pests

All removals were completed under permit from April 2022 – September 2024. The Victorian Fisheries Authority (VFA) is responsible for managing the permits associated with removing Noxious Aquatic Species. This was a straightforward process

Sporophyll at different stages of development *Kade Mills*



without a fee that required the names of the team leaders, the locations weeding was to take place and the method of removal. VFA were extremely supportive of the program and made the permit process quick and simple.

In the water, Undaria were categorised into two groups, those with developed sporophylls (part of the algae containing spores) and those without. Algae without developed sporophylls were removed by cutting above the holdfast and placing it into a catch bag.

Initially, algae with developed sporophylls were removed as per the methods outlined in Pocklington (2020). Summarised – this involves cutting the algae above and below the sporophyll placing the sporophyll in a plastic bag and sealing it to reduce spore dispersal. The top (blade) of the algae can safely remain in the environment as can the bottom (holdfast).

This method proved too slow to remove a significant number of algae at locations with dense beds of Undaria. Many groups were also against introducing more plastic into the environment. To allow for more Undaria to be removed a different method was used when the abundance was high. This involved removing the sporophyll by cutting above it to remove the blade then cutting below it, above the holdfast then transferring the sporophyll to a floating container as quickly as feasible. This method is similar to how PV initially removed Undaria at Popes Eye. The algae and associated water were then taken to shore and processed. This allowed for large numbers to be removed quickly and reduce the number of spores released into the environment.

Disposal of Undaria involved storing the algae in tubs and removing them from the area. Composting them was popular and many participants processed Undaria for food. Participants were informed of the need to thoroughly wash all of their gear after the dives to avoid spreading spores to other locations.

Data collection

Data sheets recorded the effort (number of divers, time in the water etc.), the quantity of Undaria removed, presence of sporophyll, size category and the number of interactions with the public (Appendix 4). Initially data sheets required participants to sort Undaria into 10 cm size groups (i.e. 0–10 cm, 11–20 cm etc.). This required a large amount of time post dive discouraging some participants so the sizing was simplified to above and below 30 cm.

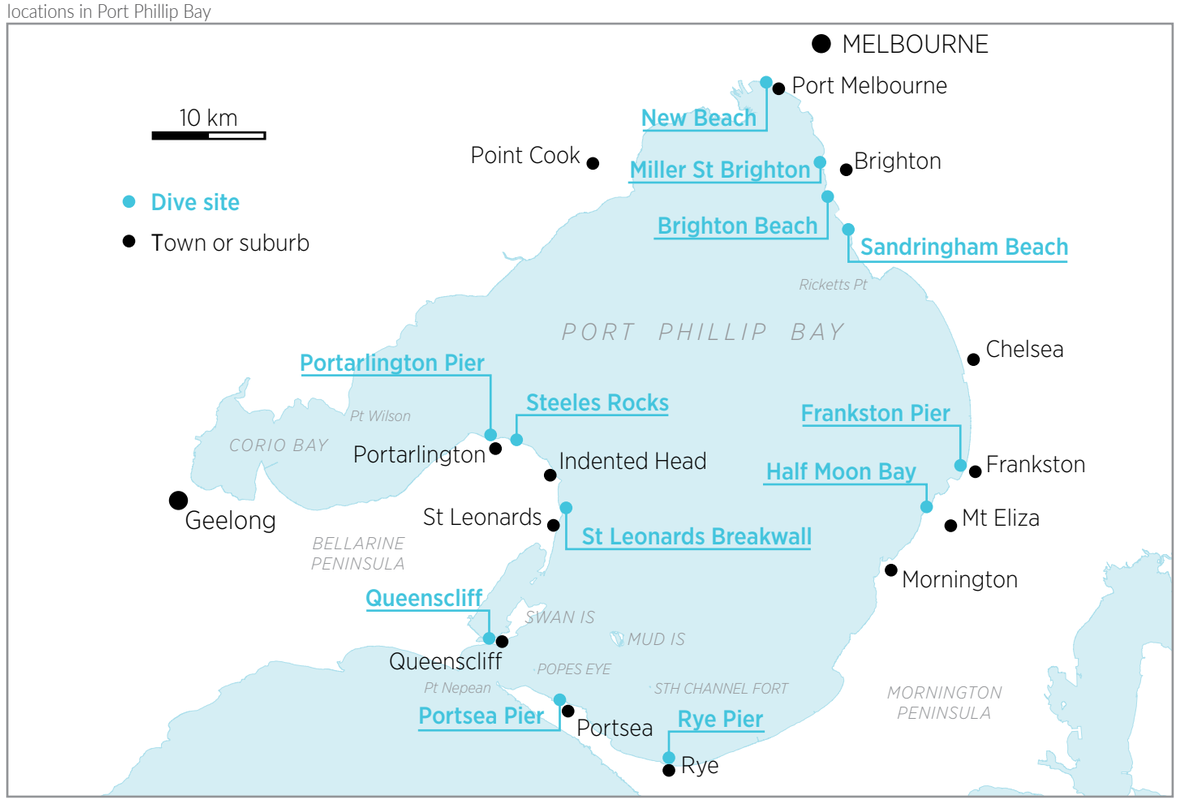


Fig. 2: Underwater weeding locations in Port Phillip Bay

Results

Four hundred and twenty-two participants removed 11,767 Undaria at 12 locations in Port Phillip Bay (Fig. 2). Only 11 Golden Kelp *(Ecklonia radiata)* were mistakenly removed; all at one location by one participant. In addition, 4,343 Northern Pacific Seastars were removed and large quantities of marine debris throughout all events.[4]

Beginning in April 2022 and finishing in September 2024, a total of 58 events were run with removal occurring at 49 of them. At seven events in Autumn and two in Winter, no Undaria was found or removed. An additional 28 events were planned but had to be cancelled due to unfavourable conditions. The number people at each removal event varied from 2 to 17. At events, participants fielded questions from 356 members of the public regarding the work they were undertaking and informed them about marine pests in Port Phillip Bay.[5]

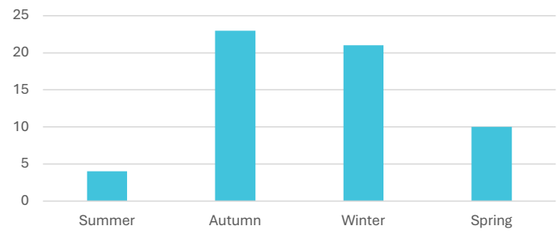


Fig. 3: Total number of Undaria removal events per season

Removal events occurred throughout the year with over 20 occurring in Autumn and Winter with less in Spring (10) and only four in Summer (Fig. 3).

The average number of participants per season was within the same range during Autumn (6.8), Winter (8.3) and Spring (7.8) with less in the Summer (3.3) (Fig. 4).

More Undaria were removed during Winter (5,838), followed by Spring (2,991), Autumn (2,202) with 736 removed in Summer (Fig. 5). Each participant removed more Undaria per hour in Winter (53) than any other season of the year (Fig. 6).

The mean number of Undaria removed that did not have sporophylls was similar in Autumn (14.7) and Spring (14.7) peaked in Winter (17.9) and decreased in Summer (8.1) (Fig. 7).

More mature Undaria with a sporophyll were removed in Winter (35.7), Spring (26) and Summer (36.2) than Autumn (6.2) (Fig. 8).

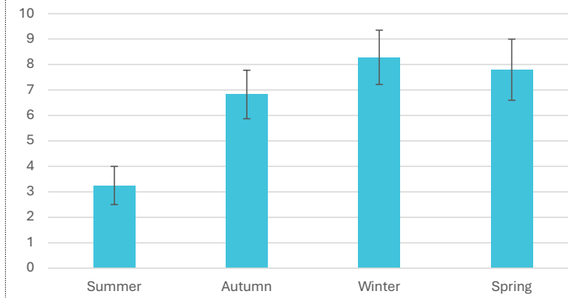


Fig. 4: Mean number (±SE) of participants per event per season

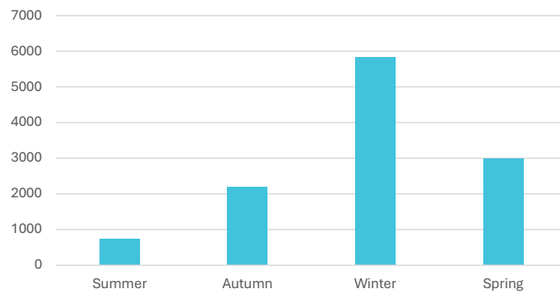


Fig.5: Total number of Undaria removed per season

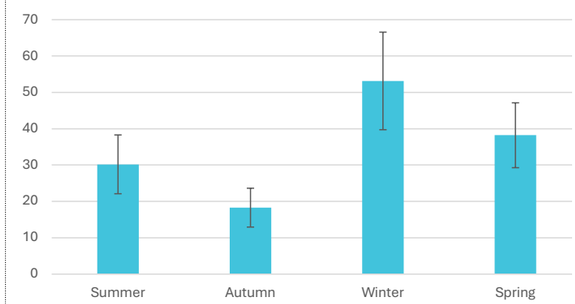


Fig. 6: Mean number (±SE) of Undaria removed per hour by each participant per season

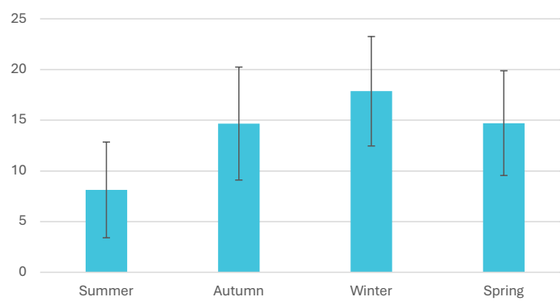


Fig. 7: Mean (±SE) number of Undaria without a sporophyte removed per diver per hour

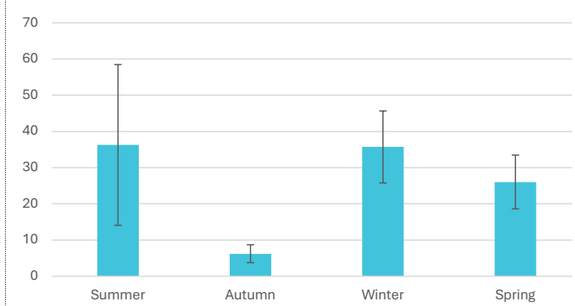


Fig.8: Mean (±SE) number of Undaria with a sporophyte removed per diver per hour

Oven-dried Undaria (wakame)
Liz Harper

Discussion

The strong participation and high number of events demonstrate a clear and sustained interest within the Port Phillip Bay marine community in actively contributing to the removal of Undaria from their local dive sites. Moreover, the concurrent removal of marine debris and Northern Pacific Seastars *(Asteria amurensis)* during these Undaria dives highlights the sense of stewardship that divers have over the health and maintenance of their local marine environment. This proactive engagement not only reflects a commitment to biodiversity preservation but also underscores the broader environmental responsibility embraced by the local diving community.

The provision of clear, well-structured resources to assist in the identification of Undaria and the thorough training of participants were instrumental in minimising the removal of non-target species. During the project's first event, one participant mistakenly removed golden kelp instead of Undaria. Upon realising the error, the individual was promptly paired with an experienced diver to refine their identification skills. This incident led to the recommendation that first-time participants be paired or grouped with seasoned Undaria weeding divers during removal activities. This approach proved highly effective, as no further accidental removals occurred, ensuring the accuracy and success of the project.

Most events were done over Autumn and Winter as the initial plan was to have monthly events from April to August, to target Undaria before the sporophyll develops as well as during its peak growth season from April to June (Primo et al., 2010). The goal being to reduce the number of Undaria that release spores into the water. However, it quickly became apparent to the marine community that the sheer abundance of Undaria and cancellation of almost one in three planned events due to inclement weather necessitated a more flexible approach. As a result, removal events were extended and conducted throughout most of the year for the last two years of the project resulting in lower number of events during Spring and Summer. Adding to this is the fact that Spring and Summer are particularly busy seasons for dive businesses and groups, as they focus on training new divers and participating in other events.

Participation was steady throughout Autumn to Spring and it was great to see people willing to dive through Winter as this is generally a time of the year when less people enter the water, (ReefWatch data unpublished). The project succeeded in providing a way for people to continue to connect and be involved in on-ground works in Port Phillip Bay.

The removal of more Undaria over Winter and the higher rate at which Undaria were removed during this season is expected, as this is when the water temperature is ideal for Undaria growth (Epstein & Smale, 2017). The low number removed and the slower rate of removal in Autumn is likely due to water temperatures at the end of Autumn still being at 17–17.5°C, when sexual reproduction is more favourable when water temperatures is 9.5–15.5°C (Epstein & Smale, 2017).

The removal of young fronds and mature Undaria with sporophylls varied seasonally, reflecting the species' lifecycle and response to water temperature. During the colder months (Winter and Spring) in Port Phillip Bay, recruitment peaks, which resulted in the removal of younger Undaria during this time. Undaria that are not removed grow to a reproductive stage, developing sporophylls in late Winter/Spring. The reproductive phase extends into early Summer, after which Undaria begins to senesce as water temperatures rise. This seasonal pattern underscores the importance of timing removal efforts to target both the recruitment phase and the reproductive stage, maximising the effectiveness of weeding activities.

Challenges and lessons learnt

The first challenge was to ensure that only Undaria were removed. With only one person removing Golden Kelp *(Ecklonia radiata)* at the very first event, the introduction of pairing up divers experienced with removals with divers not experienced prevented further occurrences.

The weather will always be a challenge when planning events. There was a trade-off between providing a consistent time for events (e.g. first Saturday of the month) and flexibility to plan around the weather. The consistent timing enabled dive stores to plan their monthly calendar and provide participants with a known time for events.

Portarlington Breakwall has a large amount of Undaria, golden kelp and other algae making it a great location to train divers in identification and removal of Undaria. However, after safely completing a couple of dives at the location we were contacted by PV and informed that we were unable to continue using the site and required an access agreement to continue the project on assets (piers, breakwalls and jetties) in Port Phillip Bay managed by PV.

The process was straightforward and the staff at PV were helpful. The agreement also contained information on the state of some structures (i.e. spalling concrete) and helped to improve the safety of the project.

UNDERWATER WEEDING IN PORT PHILLIP BAY VNPA REEFWATCH

Sustainability and future plans

Most groups plan to continue removing Undaria at their local sites and have incorporated it into their annual dive calendar. A portal for data has been created on the Atlas of Living Australia[6] for the ongoing collation of data. Many individuals have submitted their own collection permit and plan to continue with removals at their local sites.

Groups weeding on natural reef are focussing their attention on weeding Undaria where it is nestled among native algae before weeding areas where it has extensive coverage. This reduces pressure on the native algae beds by preventing Undaria from establishing in these areas. It is also often the areas divers most want to explore.

One of the key questions that we would like to answer is does the removal of Undaria help with the regrowth of with native species. We are in the process of working Southern Seagreens (a business that holds a license to remove Undaria and use it for human consumption) to help answer this question. This work is ongoing and outside the scope of this project.

As Undaria growth time is during Winter, the project is best run at a time when there are fewer competing events and most groups are less busy and looking for motivation to get in the water.

Community impact

Below are quotes from underwater weeding leaders that highlight the impact of the project.

'Taking part in the Underwater Weeding project has been a great way of learning more about Undaria and how it is invading our waters, as well as being able to give back to the underwater environment I love and use so much. I have led many dives with volunteers over the last couple of years as part of this project to remove Undaria from Frankston Pier. Through this I have taught a lot of people about the impact and ecology of Undaria, and the response has been wonderful, with people wanting to learn and take part, and to give back to the environment just like I have been doing. And it's not only the divers taking part who are learning, but the public who see us collecting the Undaria and who want to learn about what we are doing. This has been a great way to educate a broad audience about the impact of this species in our bay.'

'The Undaria Underwater Project was an incredible opportunity to connect with like-minded individuals passionate about marine conservation. It allowed me to take meaningful action in protecting our local ecosystems while sharing the joy of underwater exploration with others. For everyone involved, it was a chance to learn, contribute, and build a stronger sense of community through our shared commitment to the environment.'

Happy divers at Portarlington
Kade Mills

Conclusion

The marine community of Port Phillip Bay has made significant strides in removing large amounts of Undaria across the bay. This collaborative effort, often referred to as 'underwater weeding,' gained increasing support throughout the project and has now become a regular and highly anticipated activity for many participating groups. This continuity is critical, as it fosters ongoing awareness and proactive management of marine pests in Port Phillip Bay.

Notably, the Undaria removed during these efforts was repurposed by participants and the wider community, either as compost or for human consumption. This innovative approach ensured that no material went to landfill. In some cases, most of the Undaria removed was taken by individuals outside the participating groups, demonstrating the broader appeal and utility of the initiative. The ability to repurpose the harvested material has enhanced community interest and will likely contribute to sustained support for the project.

Further research would be valuable in assessing the long-term ecological benefits of Undaria removal. Partnering researchers with community groups to investigate whether removal facilitates the recovery of native algal species over 5–10 years could provide essential insights. Additionally, with trials underway to restore Golden Kelp in Port Phillip Bay, scaling up these efforts presents an exciting opportunity. Mobilising the engaged community to remove Undaria from areas targeted for kelp restoration, as well as maintaining these areas post-restoration, could significantly bolster these efforts.

This project, alongside efforts by Port Phillip EcoCentre, Earthwatch St Kilda and Pt Cook Marine Care, has significantly enhanced public understanding of marine pests in Victoria. Whether through hands-on participation in pest removal or through the many conversations sparked by this work, community members are increasingly informed and engaged in marine biosecurity.

Today, Port Phillip Bay boasts a dedicated and informed network of community members actively contributing to marine biosecurity. This group represents a valuable resource for future initiatives, ensuring continued progress in protecting and restoring the bay's marine ecosystems.

Divers exiting the water at Brighton with their haul
Kade Mills

Appendix 1: Identifying Undaria

VICTORIAN NATIONAL PARKS ASSOCIATION
Be part of nature

IDENTIFYING UNDARIA: DIFFERENCES BETWEEN UNDARIA AND GOLDEN KELP

EXAMINE

IDENTIFYING UNDARIA: DIFFERENCES BETWEEN UNDARIA AND GOLDEN KELP

Undaria (left) and Golden Kelp (right) growing on a rocky reef

Undaria pinnatifida's ability to rapidly colonise rocky reefs, especially patchy or disturbed environments, poses a threat to native Golden Kelp (*Ecklonia radiata*) in our bays. Removal of *Undaria* through underwater weeding projects may help boost resilience of our native kelp, but it can be a little tricky to tell the two apart. Here are a few tips!

Juvenile Golden Kelp (left) and adult Golden Kelp (right) showing lack of central rib and spiky edges

Golden Kelp

(Ecklonia radiata)

- No central "rib"
- Spikes often present on edge of lamina/blades
- Not slippery to touch

Juvenile *Undaria* (left) and adult *Undaria* (right) showing distinct central rib and smooth edges

Undaria/wakame

(Undaria pinnatifida)

- Has a "rib" down the centre
- Smooth, rounded lamina/blade edges
- Slippery to touch

VICTORIAN NATIONAL PARKS ASSOCIATION | 1

EXAMINE

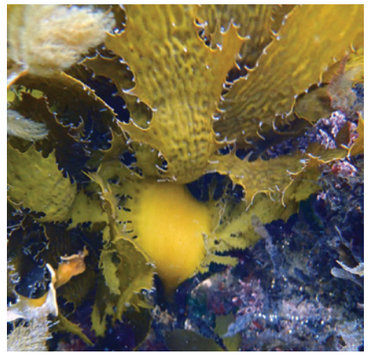
IDENTIFYING UNDARIA: DIFFERENCES BETWEEN UNDARIA AND GOLDEN KELP

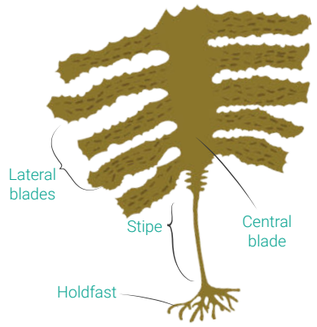
Undaria vs. Golden Kelp - juvenile phase

***Undaria*/wakame/Japanese Kelp** (introduced)
Undaria pinnatifida
© Kade Mills

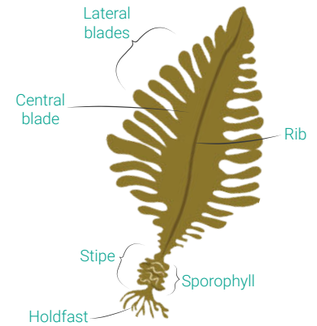
Golden Kelp (native)
Ecklonia radiata
© Tristan Graham

Adult Golden Kelp





Adult *Undaria*

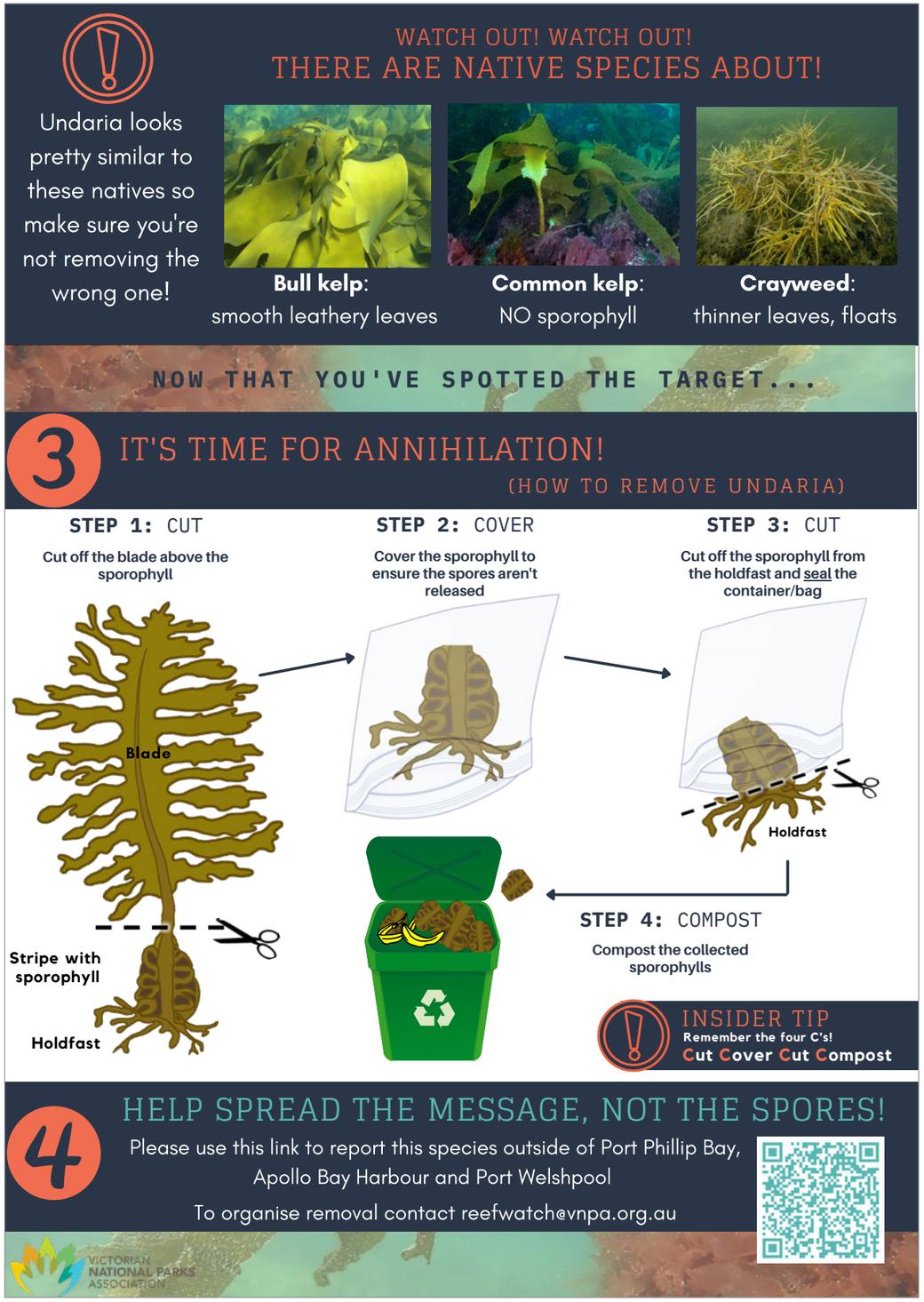


Keep an eye out for the "Viennetta"

- Undaria's reproductive structure, the **sporophyll**, is highly wrinkled and easy to spot in mature plants (left image), resembling a Streets Viennetta. The sporophyll starts forming at early stages, seen first as a twist in the base of the **stipe** near the **holdfast** (right image).
- Golden kelp do not posses a wrinkled sporophyll and juvenile plants will not show a twisted stipe.

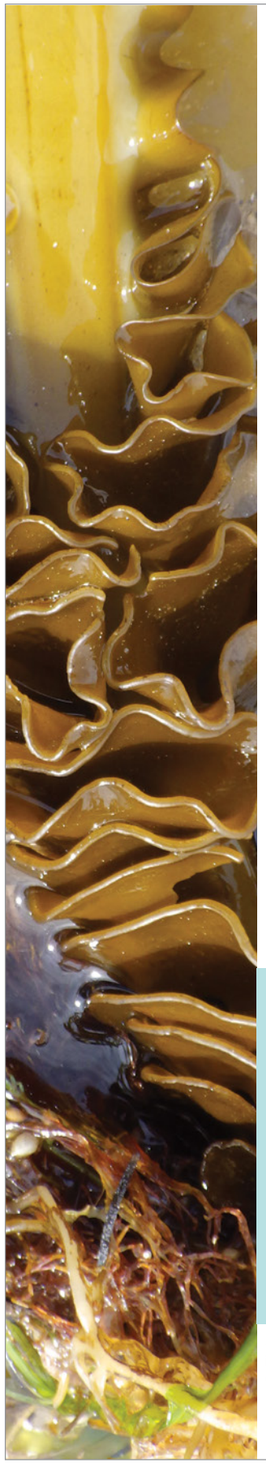
UNDERWATER WEEDING IN PORT PHILLIP BAY VNPA REEFWATCH

Appendix 2: Operation Save the Bay



UNDERWATER WEEDING IN PORT PHILLIP BAY VNPA REEFWATCH

Appendix 3: A Reef Watcher's Guide to Undaria pinnatifida

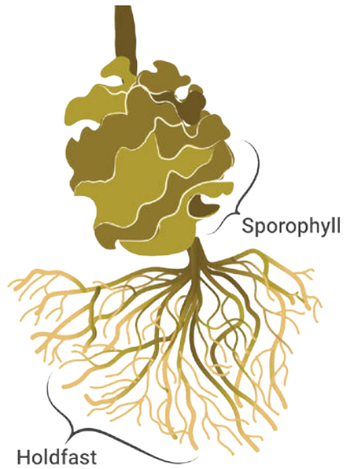


What is *Undaria*?

Names: Japanese or invasive kelp, wakame, *Undaria pinnatifida*, *U. pinnatifida* or *Undaria*.

Distribution: *Undaria* is native to the cool waters of the northwest Pacific and may be found along the coasts of Japan, Korea, China and Russia. The species has spread to New Zealand, the European Atlantic coast, central Patagonia, California and Australia. In Australia, it was first recorded in Tasmania in 1988 and has since spread to South Australia, Apollo Bay and is prevalent in Port Philip Bay.

Occurrence: *Undaria* is commonly found inhabiting low intertidal or shallow subtidal habitats, requiring a hard substrate to attach its holdfast. In addition to rocky reefs, *Undaria* is often found growing on artificial structures like piers, wharf piles, mooring ropes, pontoons and even boats. It is capable of forming thick canopies in depths down to 20 m.



The holfast is the root-like structure that anchors *Undaria* to a substrate (hard surface). *Undaria's* holdfast is a complex root system resembling a birds nest | Nicole Mertens

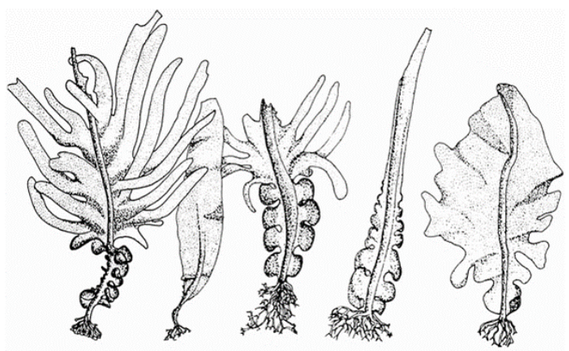
A map of the distribution of *Undaria pinnatifida.* Cryptogenic: unknown origin, may be native or introduced | Source: Marine Pest Sectoral Committee (2015), Rapid response manual for *Undaria pinnatifida*, Department of Agriculture and Water Resources, Canberra. CC BY 4.0

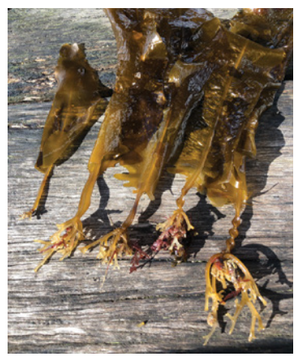
UNDERWATER WEEDING IN PORT PHILLIP BAY VNPA REEFWATCH

Undaria is known for ...

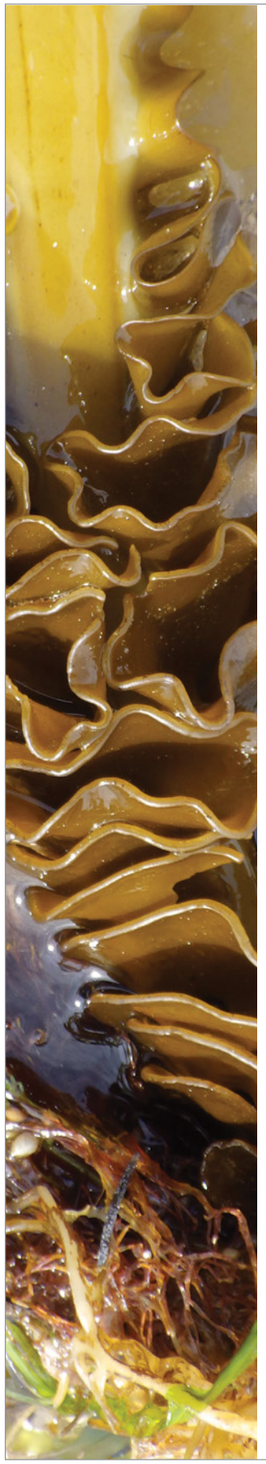
Being on the "**List of 100 worst globally invasive species**", as compiled by the International Union for the Conservation of Nature Invasive Species Specialist Group. Why? Read on.

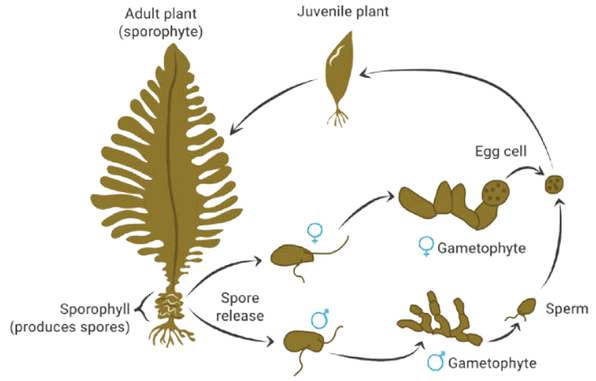
- Its reproductive prowess. Adults are capable of releasing millions of **zoospores** (microscopic swimming spore) into the surrounding water per gram of reproductive tissue. In fact, a single plant can release up to **100 million** zoospores each year. This usually takes place as summer approaches.
- Its **sporophyll**. Mature *Undaria* plants (**sporophytes**), have an easily identifiable reproductive structure called a "sporophyll". It has a corrugated appearance, not unlike a Streets Viennetta (the iconic Australian dessert!). The structure functions as the plant's reproductive organ and is found towards the base of the plant. Juveniles **do not** have a sporophyll and can be confused with the native juvenile Golden Kelp (*Ecklonia radiata*).
- Its size. Mature plants can reach up to 3 m in length!
- Its ability to grow. Sporophytes undergo a rapid growth phase (in Port Philip Bay, this begins in May). During this period, they can grow **10-20 mm per day**. Adults mature after approximately 50 to 70 days.
- The longevity of its germinated spores (**gametophytes**). Sporophytes generally live for around a year. However, gametophytes floating in the water column may survive for up to 2.5 years! Gametophytes usually stay dormant over the summer to avoid unfavourable high temperatures for development. This creates a 'seed bank', effectively allowing *Undaria* to recruit continuously.





Undaria differs in appearance over the course of its growth phase and as a mature sporophyte | Left: Food and Agriculture Organization (United Nations), Right: Kade Mills





The life cycle of *Undaria pinnatifida* | Source: Jim Sinner, Barrie Forrest and Michael Taylor (2000), A Strategy for Managing the Asian Kelp *Undaria*: Final Report, Ministry of Fisheries, New Zealand

A model invader

Dispersal: How does *Undaria* move?

Like a common garden weed, *Undaria* spreads with ease. The following are the main mechanisms by which this pesky kelp is dispersed:

- **Ocean currents** – spores can be dispersed naturally by currents over distances of tens or even hundreds of meters!
- **Ship ballast** – water taken aboard vessels to maintain stability may contain microscopic life stages of species like *Undaria*. When this water is discharged at a location far from where it was sourced, viable spores can be released into the new environment and establish.
- **"Hitching a ride"** – *Undaria* can attach to vessels and artificial structures, resulting in them getting transported to new locations. This highlights why it is so important to check vessels in ports or marinas for unwanted "hitchhikers".
- **Accidental imports** – *Undaria* has been imported to areas unintentionally by being attached to shellfish products.

Temperature: How does *Undaria* grow?

The growth and reproduction of *Undaria* is linked to water temperature, following a seasonal pattern.

i. Sporophyte recruitment occurs in winter: temperature range 5 - 27 °C.
ii. Mature plants become reproductive in spring: settlement of spores commonly occurs between 11 and 25 °C.
iii. Finally, die back (**senescence**) takes place over summer: when individuals are exposed to water temperatures of 24 °C or above.

In Port Philip Bay, the main growth period of *Undaria* occurs between A**pril and June**. It usually reaches maximum abundance in October - November, declining in February - March.

What has *Undaria* replaced?

This seems to depend on where it has been introduced, as *Undaria* has been found to displace native coralline algae in New Zealand yet is considered non-aggressive to native species in France.

A study in Port Phillip Bay has suggested that *Undaria* is relatively benign; however, the study was only completed at one location in the northern end of the bay and may not be reflective of other locations throughout the bay.

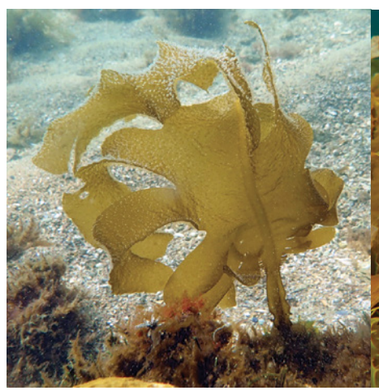
Regardless of the variability of its impact, *Undaria's* ability to rapidly colonise disturbed or "patchy" areas has the potential to decrease the density and diversity of native flora and fauna. Consequently, its removal will provide native flora with a more favourable chance to establish and persist at your local site.

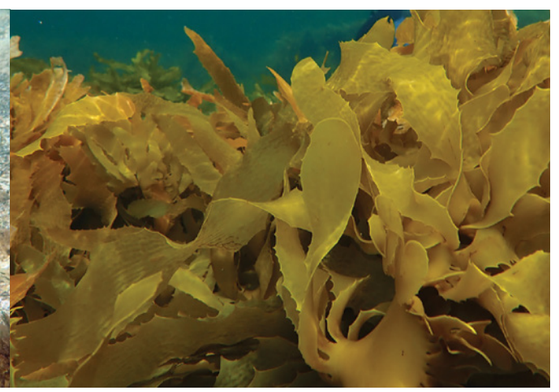
What affords this seaweed such a competitive advantage?

Most large macroalgae are **perennial**. This means they are long-lived: some species can survive for up to 10 years!

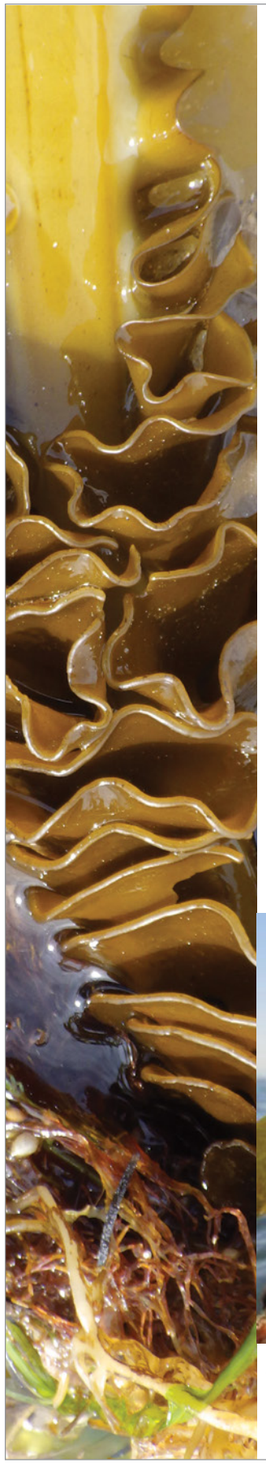
Undaria on the other hand are **annual**, with **recruitment** (settlement and subsequent growth of plants) occurring in multiple "pulses" throughout the year. The ongoing recruitment provides *Undaria* with the ability to exploit bare patches of habitat that can occur during periods when native macroalgae experience natural die back.

Here in Victoria, *Undaria* and *Ecklonia radiata* (Golden Kelp) occupy similar habitats. The potential for *Undaria* to "steal" space from the native Golden Kelp is of concern. However, despite these concerns, there has been minimal work done to suggest that *E. radiata* is being encroached upon by *Undaria* at this stage.





Left: the invasive kelp *Undaria pinnatifida* | India Ambler
Right: the native *Ecklonia radiata*, also known as Golden Kelp | Nicole Mertens



Underwater weeding and other controls

Why are we doing this? We're never going to get rid of this weed…

Getting rid of any marine pest is incredibly challenging, with success stories exceedingly rare. Successful eradication of marine pests has depended upon early detection and the ability to contain the infestation.

Given that we know *Undaria* has been in the bay since the 90's and it is present in all parts of the bay, you might be wondering why we are doing this as considering complete eradication of *Undaria* in Port Philip Bay is unlikely.

Fair enough to wonder. However, weeds are omnipresent in our terrestrial landscapes, yet we still weed our garden, local reserve, and National Parks. We continue to weed for many reasons e.g. therapy, or aesthetics. Most importantly though we weed to give our preferred species (in our case native seaweeds) a greater chance of survival, encouraging them to flourish.

Underwater weeding of *Undaria* can also play a role in limiting the spread of *Undaria* into pristine areas of the bays and beyond.

What else can we do to help? A call to arms

Wash your gear! Dive gear, fishing gears, boats etc. all have the potential to transport spores or plants from one location to another. You should be washing your gear anyway, this is just another reason to give it all a good scrub.

Another way to help is to **report suspected sightings of *Undaria* at locations outside of Port Phillip and Apollo Bay.** This easy step can help stop the emergence of *Undaria* in new areas. If you do see *Undaria* outside its known range, report your sighting to **marine.pests@ecodev.vic.gov.au**. Include a photograph, date, time and details of the location found.

A diver holds up an Undaria plant for closer inspection | © Mark Rodrigue

UNDERWATER WEEDING IN PORT PHILLIP BAY VNPA REEFWATCH

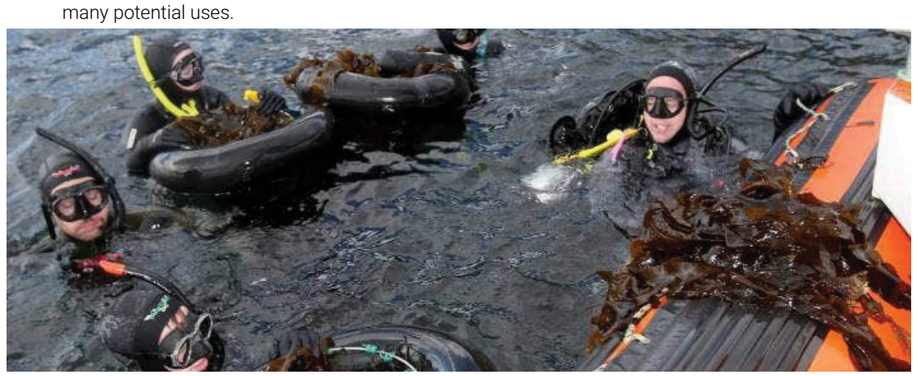
But wait, there's more. We can eat it, too!

Many people will have tried some sort of seaweed in their life. Here are some interesting facts about the farming and consumption of *Undaria*.

- Kelp is a very versatile product. It has an **umami** quality about it, a term that roughly translates to "essence of deliciousness" in Japanese. This makes it highly moreish – and ultimately a great ingredient to work with for chefs across the globe.
- "Wakame", another name for *Undaria*, usually comes dried and salted and can be used in a variety of dishes. Sprinkle it over salads, blend it to create a sauce, or simply add it to soups – the list goes on!
- Chefs in Australia are valiantly endeavouring to unlock the full potential of seaweed products like wakame. Although franchises like Sushi Train have helped with its integration into society, there still remains the task of educating people about the kelp itself and its many potential uses.

Did you know that *Undaria* is primarily used as a source of human food? It features heavily in many Asian cuisines, particularly throughout Japan, Korea and China | www.gastronomiavasca.net, accessed 3/8/22

Despite this potential, seaweed farming is a relatively novel industry in Australia. Cultivation is still operating on a very small scale – primarily due to a lack of research on the biology of the kelp itself and hence its commercial viability.



Divers from the university of Otago in New Zealand have been harvesting Undaria for research purposes | © Kavinda Herath / STUFF

Appendix 4: Underwater weeding data sheets

Underwater weeding data sheets

Supervisor/s.....

Location.....

Date.....

 # Divers.....

 # Divers weeding for first time.....

Time divers in..... **Time divers out.....**

Area Weeded (i.e. end of pier / end of pier and halfway to shore / 10 piles on the northern side)

.....

Anything else removed - accidental or on purpose. i.e. Ecklonia, Northern Pacific, Rubbish etc

.....

Depth range of most plants.....

Depth range of most plants.....

Length (cm)	Number of plants with NO SPOROPHYTE
0-30	
30+	

Length (cm)	Number of plants with SPOROPHYTES
0-30	
30+	

Number of people that ask what you are doing

.....

Photograph sheet & send to Kade
0407 363 719

UNDERWATER WEEDING IN PORT PHILLIP BAY VNPA REEFWATCH

Endnotes

1 https://southernseagreens.com/, https://www.theaustralianseaweedcompany.com/
2 https://www.ascotindustries.co.nz/hose-holder/seaweed-liquid-fertiliser.html
3 https://www.marinova.com.au/
4 https://biocollect.ala.org.au/acsa/project/index/99915577-ada2-48ef-907e-193550ac66bb
5 https://biocollect.ala.org.au/acsa/project/index/99915577-ada2-48ef-907e-193550ac66bb
6 https://biocollect.ala.org.au/acsa/project/index/99915577-ada2-48ef-907e-193550ac66bb

Acronyms

DEECA	Department of Energy, Environment and Climate Action (Vic)
IUCN	International Union for Conservation of Nature
MSP	Marine spatial planning
PV	Parks Victoria
VFA	Victorian Fisheries Authority
VNPA	Victorian National Parks Association

References

Brown, MT & Lamare, MD (1994) 'The distribution of *Undaria pinnatifida* (Harvey) Suringer within Timaru Harbour, New Zealand'. *Bulletin of Japanese Society of Phycology (Sôrui)*, 42, pp.63-70.

Campbell, SJ & Burridge, TR (1998) 'Occurrence of Undaria pinnatifida (Phaeophyta: Laminariales) in Port Phillip Bay, Victoria, Australia'. *Marine and Freshwater Research*, 49(5), pp.379-381.

Carnell, PE & Keough, MJ (2014) 'Spatially variable synergistic effects of disturbance and additional nutrients on kelp recruitment and recovery'. *Oecologia*, 175, pp.409-416.

Commissioner for Environmental Sustainability Victoria (2021) *State of the Marine & Coastal Environment Report*, Victorian Government, Melbourne.

Crockett, P, Johnson, K, Brenker, M, Ierodiaconou, D & Carnell, P (2017) '*Undaria pinnatifida* in Port Philip Bay Marine Sanctuaries: Removal strategies and interactions with the native algal canopy'. *Parks Victoria Technical Series 113*. Parks Victoria, Melbourne.

Epstein, G & Smale, DA (2017) '*Undaria pinnatifida*: A case study to highlight challenges in marine invasion ecology and management'. *Ecology and Evolution*, 7(20), pp.8624-8642.

Floc'h, JY, Pajot, R & Mouret, V (1996) '*Undaria pinnatifida* (Laminariales, Phaeophyta) 12 years after its introduction into the Atlantic Ocean'. In Fifteenth International Seaweed Symposium: Proceedings of the Fifteenth International Seaweed Symposium held in Valdivia, Chile, in January 1995 (pp. 217-222). Springer Netherlands.

Hewitt, CL, Campbell, ML, McEnnulty, F, Moore, KM, Murfet, NB, Robertson, B & Schaffelke, B (2005) 'Efficacy of physical removal of a marine pest: the introduced kelp *Undaria pinnatifida* in a Tasmanian Marine Reserve'. *Biological Invasions*, 7, pp.251-263.

Pocklington, JB (2020) 'A method for safely removing the invasive kelp *Undaria pinnatifida* (Harvey) Suringar'. *The Victorian Naturalist 'The Pest Issue'* 137(6):246-251.

Primo, C, Hewitt, CL & Campbell, ML (2010) 'Reproductive phenology of the introduced kelp *Undaria pinnatifida* (Phaeophyceae, Laminariales) in Port Phillip Bay (Victoria, Australia)'. *Biological Invasions*, 12(9), 3081–3092.

Schiel, DR & Thompson, GA (2012) 'Demography and population biology of the invasive kelp *Undaria pinnatifida* on shallow reefs in southern New Zealand'. *Journal of Experimental Marine Biology and Ecology*, 434, 25–33.

South, PM & Thomsen, MS (2016) 'The ecological role of invading *Undaria pinnatifida*: an experimental test of the driver–passenger models'. *Marine Biology*, 163, pp.1-12.

South, PM, Floerl, O, Forrest, BM & Thomsen, MS (2017) 'A review of three decades of research on the invasive kelp *Undaria pinnatifida* in Australasia: An assessment of its success, impacts and status as one of the world's worst invaders'. *Marine Environmental Research*, 131, pp.243-257.

Spillias, S, Kelly, R, Cottrell, RS, O'Brien, KR, Im, RY, Kim, JY, Lei, C, Leung, RW, Matsuba, M, Reis, JA & Sato, Y (2023) 'The empirical evidence for the social-ecological impacts of seaweed farming'. *PLOS Sustainability and Transformation*, 2(2), p.e0000042.

Valentine, JP & Johnson, CR (2003) 'Establishment of the introduced kelp *Undaria pinnatifida* in Tasmania depends on disturbance to native algal assemblages'. *Journal of Experimental Marine Biology and Ecology*, 295(1), pp.63-90.

Undaria weeding at Brighton Beach *Liz Harper*