Determining the specificity of fish-habitat relationships in Western Port

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August 2013

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Executive Summary

A review of fish in the recent Western Port Science Review (Keough et al. 2011) concluded that fish assemblages associated with seagrass, *Zostera*, and mangroves were relatively well studied, but assemblages associated with alternative habitats such as seagrass, *Amphibolis*, the alga, *Caulerpa*, reef-macroalgae, rhodolith beds and sedentary invertebrate isolates were poorly known. This meant that, given the vulnerability of *Zostera* to declines in periods of adverse environmental conditions, the ability of fish species to utilise these alternative habitats, and therefore whether these habitats could act as a refuge habitat in the case of *Zostera* loss, was also unknown. As a result of this, the Science Review recommended that identifying the linkages between fish and alternative habitats was a high priority research need for Western Port. A secondary objective was to better understand and refine the marine asset areas previously identified for Western Port from the perspective of fish biodiversity.

Two primary methods were used for sampling alternative habitats. Underwater stereo video was used to sample habitats with higher water clarity and in some cases high-relief bottom: *Amphibolis* and reef-macroalgae in the Western Entrance segment and sedentary invertebrate isolates and rhodolith beds in the Rhyll segment. A mini otter trawl was used to sample habitats with low water clarity and low relief bottom: *Caulerpa* habitat near the eastern coast of the Rhyll segment and also *Caulerpa* habitat and a reference *Zostera* location north of Hastings in the Lower North Arm. Underwater video sampling in the Western Entrance segment was conducted in autumn and spring 2012, while the remaining sampling was conducted in spring 2012 and autumn 2013.

The results showed that species that have previously been found to be common in *Zostera* seagrass were also found in *Caulerpa* habitat, and to a lesser extent in *Amphibolis* habitat. Most species were able to utilise different plant habitats although some were more specific, such as the Weedy Seadragon (*Phyllopteryx taeniolatus*) that was only recorded in *Amphibolis* habitat. Multivariate analysis indicated that fish community structure was very similar between *Caulerpa* and previously published results for *Zostera*, as well as the reference sub-tidal *Zostera* location. One distinct difference, however, was much higher abundances of pipefish in *Zostera* habitat, supporting previous studies showing that syngnathids prefer seagrass over *Caulerpa* habitats. Although there was significant overlap of species amongst sub-tidal *Zostera* and the alternative plant habitats, this may not be the case for the fish associated with intertidal and shallow sub-tidal *Zostera* (which show differences from those in deeper sub-tidal *Zostera*) because these alternative habitats tend not occur at shallow depths.

The presence of many fish species in *Caulerpa* and *Amphibolis* habitat that have been previously recorded in *Zostera* habitat suggests that these habitats may provide a refuge for these species in the case of *Zostera* loss. However, evidence from commercial fish catches after the major *Zostera* decline in the mid-1970s suggests that species capable of utilising multiple habitats still showed significant population declines. This may be partly explained by the larger area of *Zostera* habitat relative to the alternative habitats. For example, habitat mapping in 1999 indicated that *Zostera* covered an area of approximately 100 km^2 compared with 20 km^2 for *Amphibolis* and < 10 km^2

for *Caulerpa* algae. Additionally, however, the depth and location of alternative habitats may not be as suitable for larval settlement as *Zostera* habitat. Many of the juvenile fish in the alternative habitats may have initially settled in *Zostera* habitat. Thus, alternative habitats may provide some measure of resilience by providing a refuge for a low level of fish populations in the face of *Zostera* decline, however, they will not provide protection from major population declines, and also may not provide a refuge for species where larvae settle primarily in shallow habitats or in locations dominated by *Zostera*.

Some of the previously defined marine assets for Western Port were assessed from the perspective of fish biodiversity based on this study. The currently defined asset associated with *Amphibolis* beds on the western coast of the Western Entrance segment was found have significant biodiversity value for fish, including the only populations of Weedy Seadragons recorded in the study. The *Caulerpa* beds on the eastern side of the Rhyll Segment were also found to have high fish species richness and abundance, indicating significant biodiversity value for fish. These beds, however, have not been defined as a marine asset, and the results of this study would support the addition of this area to marine assets of Western Port. In contrast to *Amphibolis* and *Caulerpa* beds, very few fish species were recorded on rhodolith beds, suggesting this asset area has low value from the perspective of fish biodiversity.

The main conclusion of the study was that although some species previously recorded in *Zostera* habitat can also utilise alternative habitats, *Zostera* habitat is nevertheless the most critical for fish biodiversity in Western Port because of its extensive spatial cover and unique role for larval settlement/development in shallow areas, as well as supporting some unique species, in particular, pipefish and seahorse species. Thus, although alternative habitats provide a potential refuge for older juveniles and adults of some fish species in the event of *Zostera* loss, the maintenance of fish biodiversity in Western Port relies on the persistence of significant areas of *Zostera*, particularly in the intertidal, shallow sub-tidal zone. The key findings of the study in relation to the major habitats are summarised below.

Zostera seagrass:

- Dominant fish habitat in Western Port covering approximately 100 km^2
- High fish species richness, dominant species include the Spotted Pipefish, Grass Whiting, Little Weed Whiting and leatherjackets (*Acanthaluteres*)
- Unique species include a diverse assemblage of conservation listed syngnathid (pipefish and seahorse) species
- Occurs in intertidal and shallow subtidal areas where it provides habitat for settling larvae of key species such as King George Whiting

Amphibolis seagrass:

- Dominant fish habitat in western entrance area of Western Port covering approximately 20 km^2
- High fish species richness, dominant species include the Sixspine Leatherjacket, Little Weed Whiting, Weedy Seadragon, and leatherjackets (*Acanthaluteres*)
- Unique species include the conservation listed Weedy Seadragon
- Habitat for economically important species such as Calamari and King George Whiting

Caulerpa algae:

- Important fish habitat on the eastern coast of the Rhyll segment of Western Port covering < 10 km^2
- High fish species richness, dominant species include the Cobbler, Wood's Siphonfish, leatherjackets (*Acanthaluteres*), and Southern Pigmy leatherjacket
- *Caulerpa* occurs deeper than *Zostera*, mostly older juvenile or adult fish
- Habitat for economically important Rock Flathead and Sand Flathead

Reef/algae:

- Small area of habitat mostly in the entrance areas of Western Port
- High fish species richness, dominant species include the Bluethroat Wrasse, Silver Trevally, Toothbrush Leatherjacket, and Sixspine Leatherjacket
- Fish generally larger than in low-relief *Amphibolis* habitat in the same area
- Habitat for economically important species such as Silver Trevally and Australian Salmon

Rhodolith beds:

- Small area of habitat occurring immediately inside the eastern entrance of Western Port
- Low fish species richness, common species were the Red Mullet and Smooth Toadfish
- Generally appears to be of limited value as fish habitat
- Low diversity and abundance of fish may relate to low habitat complexity

Introduction

The relationship between fish and their habitat is fundamental to the persistence of fish populations. The more specific the habitat requirements of fish, the more vulnerable the population is to decline where that habitat is reduced or lost. Many fish species have been shown to have strong links to seagrass beds, either as a nursery habitat offering high food levels and protection from predators, or as adult habitat, offering foraging and reproductive benefits (Bell and Pollard 1989, Jackson et al. 2001, Heck et al. 2003). Seagrass, however, is vulnerable to reduction in water quality and other environmental threats, and world-wide has declined at a rate of 7% per year since 1990 (Waycott et al. 2009).

For many fish species, whether fish are strictly reliant on seagrass habitat or whether other habitats can also be ustilised (therefore providing a refuge in the event of seagrass loss) is poorly understood. Studies have compared fish in seagrass to other structured habitats (e.g. reef/algae) as well as unvegetated mud or sand habitat (Jenkins and Sutherland 1997, Jenkins and Wheatley 1998, Guidetti 2000, Heck et al. 2003, Franco et al. 2006, La Mesa et al. 2011). Generally, there is some overlap in the fish communities in seagrass habitat and other structured habitats, while unvegetated habitats tend to support very different fish communities, usually with fewer species. Even amongst structured habitats, however, some differences in fish communities are usually found (Jenkins and Wheatley 1998, Guidetti 2000). Indeed, even within seagrass habitats, different seagrass species with varying morphological characteristics can show differences in fish assemblages (Middleton et al. 1984, MacArthur and Hyndes 2001, Hyndes et al. 2003, Kendrick and Hyndes 2003).

Fish communities can vary not only on the basis of habitat, but also spatially and temporally within a habitat. For example, seagrass beds in certain areas may support more juvenile fish than others because they are located in an area relative to current patterns that receives more larval settlement (Bell et al. 1988, Jenkins et al. 1998, La Mesa et al. 2011). Fish communities within one habitat type will also vary with depth, for example because pre-settlement larvae are distributed near the surface and therefore settlement tends to occur in shallow water (Bell et al. 1992, Smith et al. 2012). Fish community structure will also tend to show strong seasonal patterns because most fish species have distinct spawning periods that results in seasonal patterns of juvenile recruitment (Jenkins et al. 1997b).

Western Port, a temperate bay in the State of Victoria, south-eastern Australia, is a key biodiversity region as well as supporting important fisheries (Jenkins 2011, Keough et al. 2011). Western Port has a large area of intertidal mudflats dissected by dendritic channels with strong tidal currents. The tidal range of 2 to 3 metres means that a large volume of water is exchanged between the bay and the offshore waters on each tidal cycle. Western Port supports large areas of habitat supporting a rich and diverse fish community (Jenkins 2011, Keough et al. 2011). However, seagrass in Western Port, and *Zostera* in particular, has been subject to large losses, most markedly in the mid-1970s (Shepherd et al. 1989, Walker 2011).

Fish assemblages in seagrass, *Zostera* sp., habitat (Robertson 1978, 1980, Edgar et al. 1993, Edgar and Shaw 1995, Hindell et al. 2004) and mangrove, *Avicennia marina,* habitat (Hindell and Jenkins 2004, Hindell et al. 2004, Hindell and Jenkins 2005) in Western Port are relatively well studied, and some information is available on fish assemblages on unvegetated sediment habitats (Edgar and Shaw 1995, Hindell and Jenkins 2004, Hindell et al. 2004). In the case of *Zostera*, fish diversity and biomass is high relative to unvegetated habitat (Edgar and Shaw 1995), and it functions as a nursery area for juveniles of important species such as King George Whiting (Robertson 1977, Jenkins et al. 2000). The loss of *Zostera* habitat in Western Port in the 1970's was assumed to have caused a major decline in fish production, although the possibility that alternative habitats could be utilised was not considered (Edgar and Shaw 1995). It is possible that fish associated with *Zostera* can also use alternative habitats such as macroalgae. If this were the case then these habitats might act as a refuge if losses of *Zostera* occurred. Mangroves apparently do not form an important alternative habitat for seagrass fish, most likely due to their position in the upper intertidal zone (Jenkins 2011).

An example of such an alternative habitat is the alga *Caulerpa cactoides* that forms reasonably extensive beds of the on the eastern side of Western Port (Bulthuis 1981, Blake and Ball 2001) and also occurs north of Hastings (Blake et al. 2012). This relatively fragile alga generally occurs at slightly greater depths than *Zostera* but could potentially provide a viable alternative habitat for fish species.

There are a number of other potentially important fish habitats in Western Port about which little is known, both in terms of their intrinsic biodiversity value and also their potential as alternative habitats to *Zostera*. The seagrass *Amphibolis* forms extensive beds in the southern, more exposed part of Western Port (Blake and Ball 2001, Blake et al. 2012). Anecdotal information suggests that this species could form a key habitat for Weedy Seadragons and also for the spawning of Calamari, however, quantitative information on the relationship between these and other fish species within *Amphibolis* is lacking (Jenkins 2011). There are also areas of hard substrate including reefs with macroalgae (Bathgate et al. 2011), sedentary invertebrate (sponge, ascidian, bryozoan) isolates and rhodolith beds (Blake et al. 2012). Again, there is a lack of information on fish species utilising these habitats.

At present we are unsure whether key species are reliant on specific habitats or whether alternative habitats can be utilised. This means the resilience of fish populations to habitat loss and the need for protection of specific habitats to support fish populations is unclear. In this study we investigate the fish communities associated with a range of alternative habitats to well-studied *Zostera* and mangroves; including, *Amphibolis* seagrass, reef/algae, *Caulerpa* macroalgae, rhodolith beds, and sedentary invertebrate isolates (Figure 1).

The recent report to Melbourne Water "Understanding the Western Port Environment. A summary of current knowledge and priorities for future research", otherwise referred to as the Western Port Science Review (Keough et al. 2011), identified determining the linkages between fish and habitats as a high priority research need for Western Port. Critical habitats for sustaining fish at various life stages are currently unknown for many species and habitats in Western Port.

There is a need to know the value of these habitats for fish species that are important components of Western Port's biodiversity, or play an important role in the Western Port ecological system, to inform successful ongoing management to sustain populations of these fish species.

Alongside the Western Port Science Review, the Victorian Department of Environment and Primary Industries has developed a spatial map of significant marine environmental assets in Western Port, informed by the review scientific team as well as other relevant Victorian scientific experts. This map includes a number of locations in Western Port that based on current scientific understanding are particularly important for their biodiversity (including fish) or role in important ecological processes. Better scientific understanding of these asset areas, which have already been identified as ecologically important, and their resilience, has clear potential to inform improvements to future threat management. Given that this initial marine asset map was based on current understanding and expert opinion, better understanding of these areas also has potential to inform refinement of their boundaries.

Study Objectives

1) To determine the specificity of fish habitat relationships in Western Port

2) To determine the resilience of fish populations to habitat loss through the use of alternative habitats.

The focus is on fish that are important components of Western Port's biodiversity, or play an important role in the Western Port ecological system.

A secondary objective of this research is to build on the spatial map of significant marine environmental assets in Western Port by:

- Improving understanding of the important values and resilience of specific asset areas already identified, from the perspective of fish biodiversity.
- Informing future refinement of asset boundaries within these broad areas of Western Port, from the perspective of fish biodiversity.

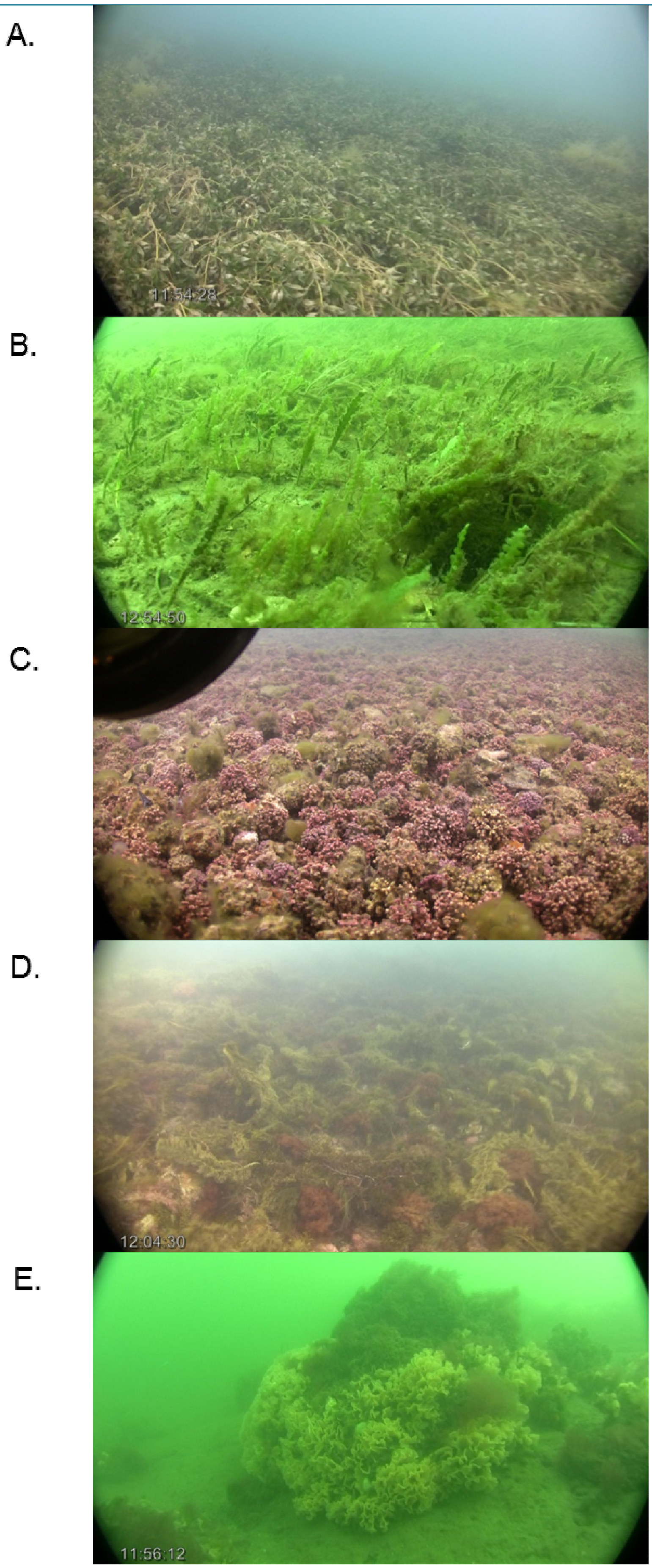


Figure 1. Habitats recorded by underwater survey in Western Port (Blake et al. 2012). A. *Amphibolis antarctica*, B. *Caulerpa cactoides*, C. Rhodolith bed, D. Reef with macroalgae, E. Invertebrate (Bryozoan) isolate

Materials and Methods

Sampling Locations

Sampling locations for *Amphibolis* seagrass and reef/algae were located in the western entrance segment (Figure 2). *Amphibolis* seagrass locations at Balnarring and Flinders consisted of beds growing on relatively flat, sedimentary bottom, while at Point Leo (near Shoreham), *Amphibolis* was growing on higher relief reef (Figure 2). Reef/algae habitat was sampled at Cat Bay on Phillip Island (Figure 2), where macroalgae such as the brown alga, *Cystophora* sp,, was associated with high-relief reef. Depths of sampling ranged from 2.5 to 7 m.

Sampling locations for sedentary invertebrate (bryozoan, sponge, ascidian) isolates were within deeper channels in the Rhyll segment at depths of 6 to 8.5 m. Rhodolith beds were sampled inside the eastern entrance to Western Port at depths of 1.5 to 5 metres (Figure 2).

Sampling locations for *Caulerpa cactoides* at Coronet Bay and Loelia Shoal in the Rhyll segment (Figure 2) were within a large area of this species growing on low-relief unvegetated sediment in depths of 4 to 7 m. In contrast, the sampling location north of Hastings in the lower North Arm (Figure 2) was mostly unvegetated sediment in 4.5 to 6.5 m depth with *C. cactoides* only associated with small invertebrate isolates growing on hard substrates such as oyster shells. In autumn, additional sampling at the same location was undertaken slightly inshore in depths of 3.5 to 4.5 m where relatively dense beds of *Zostera* seagrass occurred near their lower depth limit in this area.

Sampling Methods

This study used two primary sampling methods depending on the habitats studied. For habitats in the southern part of Western Port that had uneven substrate and relatively clear water, underwater stereo video was used. These habitats were *Amphibolis* seagrass and reef algae in the western entrance area, sedentary invertebrate isolates in the Rhyll basin, and rhodolith beds inside the eastern entrance. For *Caulerpa* and *Zostera* habitat which occurred on flat, sedimentary bottom in relatively turbid water (i.e. where video methods would be ineffective), sampling was conducted with a mini otter trawl.

Stereo video sampling

Sampling on *Amphibolis* and reef/algae locations was conducted in autumn (April-May) and repeated at the same locations in spring (October-November) 2012. Sedentary invertebrate isolates and rhodolith beds were sampled at one location in spring (November) 2012 and at a second location (in the same area) in autumn (April) 2013.

Fish were sampled using remotely deployed stereo video systems (SeaGIS Pty. Ltd., Australia) (Figure 3). Stereo systems consisted of a frame with two Canon HV20 cameras with wide angle lenses (0.7 focal length) in housings angled inward at 8 degrees, on bars 75 cm apart and 40 cm above the sea floor, and a diode arm for synchronisation of cameras. Videos were unbaited to prevent attraction of fish from nearby habitats that would not occur in normal circumstances. On each sampling day, two video frames were deployed at each of three sampling sites within the sampling location. Sampling sites were between 300 m and 1 km apart and the replicate frames were approximately 50 – 75 m apart. A live view, detachable underwater video-camera was attached to the frame on deployment to ensure the frame was on the correct habitat. Once the frame was in place correctly, the live view camera was retrieved to the vessel. Video frames were retrieved approximately 1 hr after deployment.

Mini Otter Trawl Sampling

The mini otter trawl had a 3.9 metre head rope that is kept open using small trawl doors (Figure 4). A 5 mm mesh liner in the main net and 3 mm mesh liner in the cod-end were used to retain small species and recruits of larger species (Figure 4). The mini otter trawl can be used effectively from a small research vessel (Figure 5). Four, haphazardly placed hauls were undertaken in each location on each sampling date. Each haul consisted of a 5 minute tow (from the time the warps were fully deployed until the start of retrieval) at a speed of 1-1.2 knots. A live-view video drop camera was used at the start of each tow to confirm the habitat being sampled.

Where possible fish were identified and measured (total length) immediately after capture and released alive. Difficult to identify species were anaesthetised in benzocaine solution and preserved in 95% ethanol and returned to the laboratory for identification and measurement. Where more than 30 individuals of a species were collected in a haul, a random subsample of 30 individuals was measured.

Laboratory Methods

Video was assessed using two different methods, MaxN and TiV (Smith et al. 2011, Smith et al. 2012). MaxN was the greatest number of a given fish species in a single frame and has been used to estimate fish abundance in a variety of studies (Watson et al. 2009, Becker et al. 2012, Birt et al. 2012, Harvey et al. 2012). TiV provides a measure of how fish are using each habitat and was recorded as the total time in seconds that at least one fish of a given species was in view of the left camera during each video deployment (Smith et al. 2011, Smith et al. 2012). In unbaited sampling regimes large schools of fish swimming through a habitat produce high MaxN recordings that may not reflect the abundance within that area over longer temporal scales. TiV provides an alternative to MaxN that provides an estimate of how much time species are spending in each habitat. If a fish was lost from view (i.e. hidden in seagrass or exited the screen view) and did not reappear within 10 sec it was deemed to have left the sampling area. Footage was captured and converted to AVI format using Pinnacle Studio Plus v.11 software (Pinnacle Systems Inc.). Video length was standardised for 55 min beginning at the time the cameras settled on the bottom. The computer software packages EVENTMEASURE and PHOTOMEASURE were used to record Max N and TiV data and to estimate fish lengths (SeaGIS Pty. Ltd., Australia). Orientation and location within the camera field of view prevented accurate measurement of some fish, therefore only lengths of fish that could be measured accurately (< 10% error) were recorded. To reduce the possibility of measuring the same fish twice, an interval of at least 5 minutes was applied before measuring fish of the same species and similar length.

Fish retained from mini otter-trawl sampling were identified with reference to Gomon et al. (2008), counted, and measured to the nearest mm (total length).

Data Analysis

Two-factor analysis of variance (ANOVA), with Location and Season as main effects, was used to analyse species richness, TiV and MaxN of total fish as well as TiV of key individual species, and mean length of total fish, from stereo video sampling. A two-factor ANOVA with Location and Season as main effects was also used to analyse the mini otter trawl data for species richness, total abundance and abundance of key species, and mean fish length. The data was additionally analysed for autumn only by one-factor ANOVA of the Location main effect where the additional *Zostera* location at Hastings was included. Data were checked for homogeneity of variance and normality using box plots and log(x+1) transformed where necessary to meet the assumptions of the analysis (Quinn and Keough 2002). Where effects were significant, Tukey's HSD post-hoc test was used to make pairwise comparisons.

A multivariate analogue of ANOVA, Analysis of Similarities (AMOSIM) (Clarke 1993, Clarke and Gorley 2006) was used to make comparisons of Locations and Seasons for the TiV data from stereo video and abundance data from mini otter trawl (and Locations only for otter trawl data in autumn) at the assemblage level. The analysis was based on Bray Curtis dissimilarity matrices (Clarke 1993, Clarke and Gorley 2006). The data was initially log(x+1) transformed to reduce the influence of species with high TiV or abundance. Relationships were also visualised with non-metric multidimensional scaling (nMDS) ordinations, and while stress levels obtained through this analysis should ideally be < 0.1, values < 0.2 are thought to still provide an adequate representation of relationships between replicates (Clarke 1993, Clarke and Gorley 2006). A SIMPER procedure was then used to identify the species that contributed most to treatment differences (Clarke 1993, Clarke and Gorley 2006). Species that contributed greater than 10% to dissimilarity in pairwise comparisons were considered important.

Figure 2. Sampling Locations in Western Port. Stars, *Amphibolis* habitat; Cross, reef-macroalgae; Circles, Sendentary invertebrate isolates; Triangles, *Caulerpa* habitat; Diamond, Rhodolith beds.

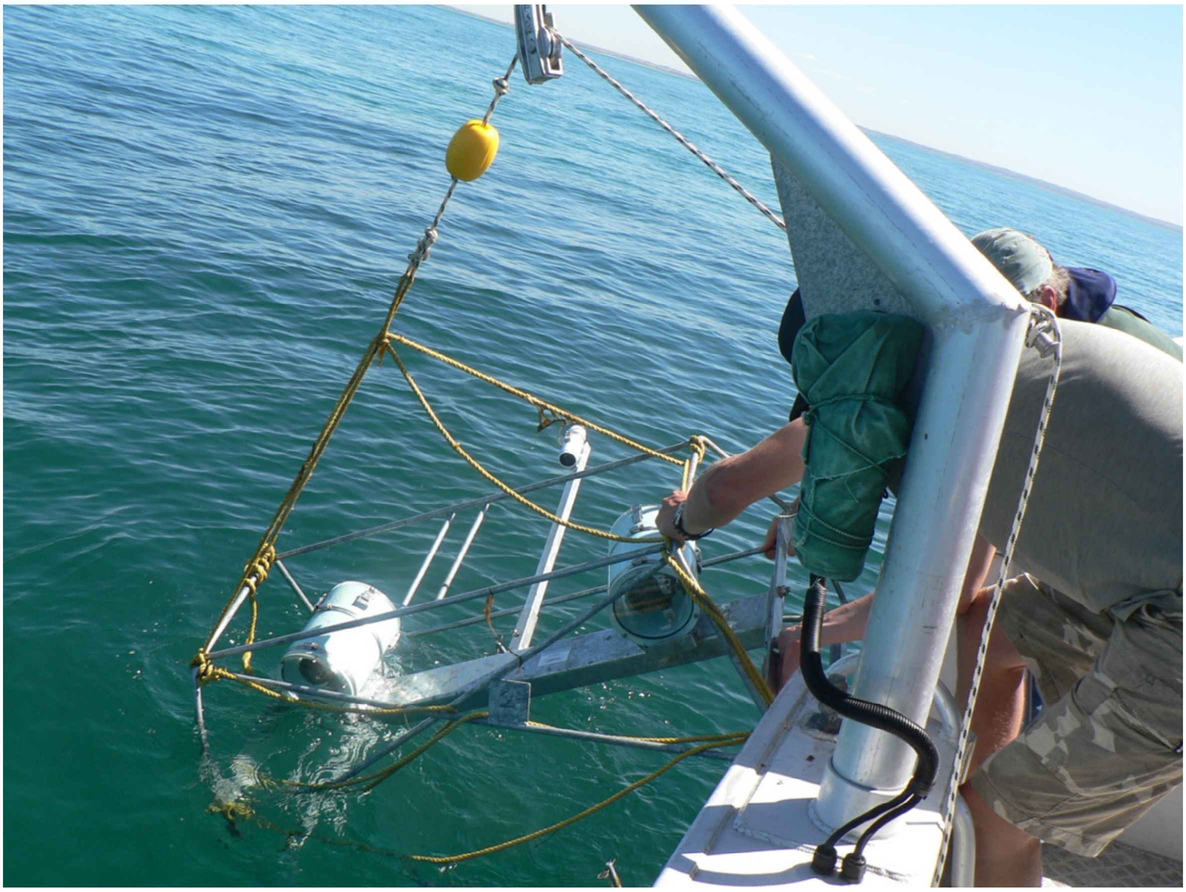


Figure 3. Deployment of stereo video camera frame

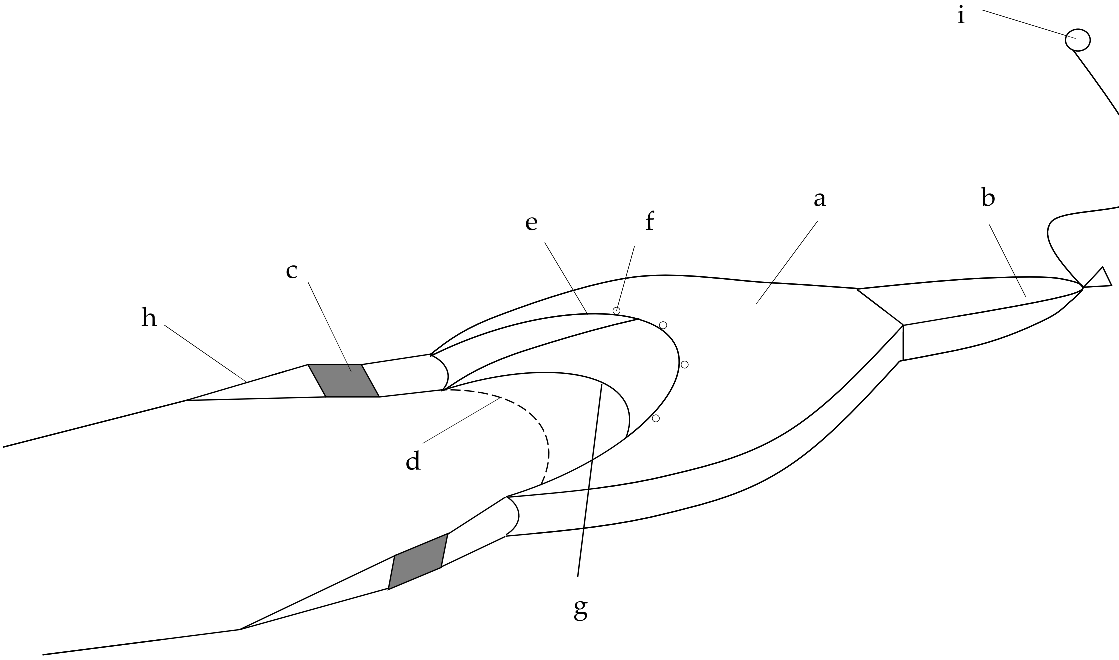


Figure 4. Diagram of mini otter trawl net employed to sample in Western Port, a) main body of net and liner (net – 38.1 mm aperture knotted nylon; liner - 5 mm aperture knotted nylon); b) codend bag of net and liner (net – 31.75 mm aperture knotted nylon; liner – 3 mm aperture knotless nylon); c) wooden otter-boards – 61 cm x 31 cm weighted with lead sheets; d) tickler chain; e) head rope – 390 cm; f) 4 foam floats; g) foot rope and chain (390 cm); h) bridle ropes; i) alternate retrieval line.

Figure 5. Mini otter trawl net deployed in Western Port

Results

Underwater Stereo video

A total of 35 taxa (including Southern Calamari) were recorded by underwater stereo video in the Western Entrance segment (Table 1). The most frequently recorded taxa were Bluethroat Wrasse, *Notolabrus tetricus*, at Point Leo and Cat Bay in both seasons (Table 1). Also occurring frequently were the leatherjackets, *Acanthaluteres* sp., and Little Weed Whiting, *Neoodax balteatus*, at Flinders in both seasons, and Sixspine Leatherjacket, *Meuschenia freyceneti* at Flinders in spring and Point Leo in autumn (Table 1). Weedy Seadragons, *Phyllopteryx taeniolatus*, occurred commonly at Flinders in autumn and Balnarring in spring (Table 1). TiV was highest for the *Acanthaluteres* sp. at Flinders and for *M. freyceneti* at Point Leo in autumn (Table 1). TiV was also moderately high for *P. taeniolatus* at Balnarring in spring (Table 1). Highest mean values of MaxN were recorded for Silver Trevally, *Pseudocaranx georgianus*, in both seasons, and Toothbrush Leatherjacket, *Acanthaluteres vittiger*, in autumn at Cat Bay, and for *Acanthaluteres* sp. at Flinders in autumn (Table 1). Important commercial and recreational fishing species that were recorded included King George Whiting, *Sillaginodes punctatus*, Gummy Shark, *Mustelus antarticus*, Australian Salmon, *Arripis* sp., and Southern Calamari, *Sepioteuthis australis*.

Species richness was significantly different amongst locations (Table 2), with richness at Flinders higher than the other locations (Tukeys test, P<0.05). There was also a significant interaction between location and season, with higher richness at the Flinders location in spring compared to autumn, while the opposite pattern occurred at Point Leo (Fig. 6). The TiV of all species combined was significantly different amongst locations (Table 2); again Flinders was higher than the other locations (Tukey's test, P<0.05; Fig. 7). Amongst individual species, TiV for *M. freyceneti* was highest at Point Leo in autumn but lowest in spring compared with all other site/season combinations (Fig. 8); for *P. taeniolatus*, TiV was highest at Balnarring in spring, slightly lower at Flinders in both seasons, and the only other record was at Point Leo in autumn (Fig. 9); and, for *N. tetricus*, TiV was highest at Cat Bay, intermediate at Point Leo and low at Flinders (Fig. 10). Although the average MaxN was higher at Flinders and Cat Bay, the data was highly variable and there were no significant differences amongst locations or between seasons (Table 2, Fig. 11).

Analysis of the fish community based on TiV using nMDS showed a relatively clear separation of two groups of locations, with Cat Bay and Point Leo locations separated from the Flinders and Balnarring locations (Fig. 12). There was a slight further separation between the Balnarring and Flinders locations but little separation in relation to season (Fig. 12). Two-way ANOSIM indicated that there was a significant difference amongst locations (Global R = 0.456, P = 0.001) but no significant difference between seasons (Global R = 0.165, P = 0.135). Pairwise tests indicated that fish assemblages at all locations were significantly different from each other with the exception of Cat Bay and Point Leo. SIMPER analysis indicated that *N. tetricus* and *M. freyceneti* contributed most to the difference between Cat Bay and Balnarring (20.70 and 11.61%

respectively) and Point Leo and Balnarring (21.81 and 12.02% respectively). For Balnarring and Flinders, *Acanthaluteres* sp. (17.39%), *P. taeniolatus* (12.68%) and *M. freyceneti* (10.60%) contributed most to the assemblage differences. For Cat Bay and Flinders, *Acanthaluteres* sp. (14.51%), *P. taeniolatus* (11.31%), *N. tetricus* (10.20%) and Odacidae (10.19%) contributed most to the assemblage differences. Finally, for Point Leo and Flinders, *Acanthaluteres* sp. (15.69%), *M. freyceneti* (11.87%) and Odacidae (11.00%) contributed most to the assemblage differences.

The mean lengths of fish recorded by stereo video were significantly different amongst locations and between seasons (Table 2, Fig. 13). Tukeys post-hoc comparisons indicated that fish at Cat Bay and Point Leo were significantly larger than at Flinders (Table 2, Fig. 13). In terms of seasonal differences, fish were larger in spring compared with autumn at all locations, with greatest differences for Cat Bay and Balnarring (Fig. 13).

The length-frequency distributions of fish recorded by stereo video were mostly uni-modal with the exception of the Flinders location where the distribution was bi-modal (Fig. 14). Small, predominantly juvenile fish less than 120 mm in length were most abundant at Flinders in both seasons and also at Balnarring in autumn (Fig. 14). Amongst the more commonly recorded species, *M. freyceneti* ranged from 180 to 360 mm (Fig. 15), *N. tetricus* ranged from 100 to 400 mm with most of the smaller (juvenile) individuals recorded at Cat Bay (Fig. 16), and *P. taeniolatus* ranged from 220 to 340 mm (Fig. 17). The length-frequencies of *Acanthaluteres* sp. varied markedly between locations, with larger individuals (160 – 260 mm), likely to be *Acanthaluteres vittiger*, recorded from Cat Bay in autumn, while small juveniles (60 – 100 mm) were recorded from Flinders in both seasons (Fig. 18).

Stereo video sampling of sedentary invertebrate isolates in the Rhyll basin and rhodolith beds immediately inside the Eastern Entrance showed a markedly lower number of species than were recorded in the Western Entrance area (Table 3). Results were conclusive for the rhodolith beds where water clarity was high, but were inconclusive for the invertebrate isolates where visibility was very poor, and the value of invertebrate isolates for fish biodiversity is still uncertain. Only flathead, Platycephalidae, and Red Mullet, *Upeneichthys vlamingii* were recorded in both seasons at the invertebrate isolates (flathead were on the sediment adjacent to the isolates) (Table 3). The highest TiV and MaxN was for flathead in the spring (Table 3). Red mullet were also recorded in both seasons at the rhodolith beds as were smooth toadfish, *Tetractenos glaber*. The highest recorded TiV at the rhodolith location was for Smooth Toadfish in the spring (Table 3).

Table 1. Frequency of occurrence (F%), mean MaxN and Mean TIV for species recorded with underwater stereo video. Colour key for maximum F% for each species: red (0-25 F%), yellow (26-50 F%), green (51-100 F%)

Common name	Species name	Flinders (*Amphibolis*-Sedimentary)						Balnarring (*Amphibolis*-Sedimentary)						Point Leo (*Amphibolis*-Reef)						Cat Bay (Reef-Algae)					
		Autumn			Spring			Autumn			Spring			Autumn			Spring			Autumn			Spring		
		F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N
SUBCLASS Elasmobranchii																									
Gummy Shark	*Mustelus antarcticus*	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	1.17	0.17
Unidentified shark		0	0	0	33	2.17	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stingaree	*Trygonoptera* sp.	0	0	0	0	0.00	0	17	1.33	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified ray		14	1.57	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ORDER Gasterosteiformes																									
Weedy Seadragon	*Phyllopteryx taeniolatus*	57	36.57	0.57	33	29.00	0.33	0	0	0	50	53.50	0.50	17	2.67	0.17	0	0	0	0	0	0	0	0	0
ORDER Perciformes																									
King George whiting	*Sillaginodes punctatus*	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	17	0.50	0.17	0	0	0	0	0	0
Silver Trevally	*Pseudocaranx georgianus*	0	0	0	33	4.00	6.50	0	0	0	0	0	0	0	0	0	0	0	0	14	2.29	6.43	33	33.33	8.17
Silverbelly	*Parequula melbournensis*	0	1.14	0	0	0.00	0	33	48.83	1.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red Mullet	*Upeneichthys vlamingii*	14	1.29	0.14	33	12.67	0.50	17	2.83	0.17	33	9.83	0.33	17	1.67	0.17	0	0	0	14	3.86	0.29	0	0	0
Australian Herring	*Arripis georgianus*	0	0	0	17	0.50	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Australian Salmon	*Arripis* sp.	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	1.67	1.83
Old Wife	*Enoplosus armatus*	0	0	0	17	3.00	0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marblefish	*Aplodactylus arctidens*	0	0	0	0	0.00	0	0	0	0	0	0	0	17	1.33	0.17	0	0	0	0	0	0	0	0	0
Dusky Morwong	*Dactylophora nigricans*	0	0	0	0	0.00	0	0	0	0	0	0	0	0	1.00	0	17	1.00	0.17	0	0	0	0	0	0
Scalyfin	*Parma victoriae*	0	0	0	0	0.00	0	0	0	0	0	0	0	17	1.67	0.17	0	0	0	14	7.71	0.14	0	0	0
Bluethroat Wrasse	*Notolabrus tetricus*	43	8.29	0.57	50	3.17	0.50	0	0	0	0	0	0	100	25.67	1.00	100	32.67	1.00	71	48.57	1.00	83	66.50	1.17
Little Weed Whiting	*Neoodax balteatus*	57	9.43	0.57	67	33.83	1.00	33	4.67	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 1 (Cont.). Frequency of occurrence (F%), mean MaxN and Mean TIV for species recorded with underwater stereo video. Colour key for maximum F% for each species: red (0-25 F%), yellow (26-50 F%), green (51-100 F%)

Common name	Species name	Flinders (*Amphibolis*-Sedimentary)						Balnarring (*Amphibolis*-Sedimentary)						Point Leo (*Amphibolis*-Reef)						Cat Bay (Reef-Algae)					
		Autumn			Spring			Autumn			Spring			Autumn			Spring			Autumn			Spring		
		F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N
Grass Whiting	*Haletta semifasciata*	14	0	0.14	50	16.50	0.83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	1.33	0.17
Rainbow Cale	*Heteroscarus acroptilis*	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	17	0.17	0.17	0	0	0	0	0	0
Herring Cale	*Olisthops cyanomelas*	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	29	3.57	0.29	0	0	0
	Odacidae	0	0	0	67	12.50	0.67	0	0	0	17	3.83	0.17	0	0	0	0	0	0	0	0	0	17	0.83	0.17
Snook	*Sphyraena novaehollandia*	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0.83	0.17
ORDER Tetraodontiformes																									
Sixspine Leatherjacket	*Meuschenia freycineti*	29	24.29	0.29	67	30.83	0.83	33	27.33	0.33	17	11.17	0.17	83	116.83	1.00	17	1.17	0.17	29	8.14	0.29	33	7.33	0.33
Horseshoe Leatherjacket	*Meuschenia hippocrepis*	0	0	0	0	0.00	0	0	0	0	0	0	0	17	0.67	0.17	0	0	0	0	0	0	0	0	0
Brownstriped Leatherjacket	*Meuschenia australis*	0	0	0	0	0.00	0	0	0	0	0	0	0	33	3.83	0.33	0	0	0	0	0	0	0	0	0
Bridled Leatherjacket	*Acanthaluteres spilomelanurus*	0	0	0	50	8.83	0.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Toothbrush Leatherjacket	*Acanthaluteres vittiger*	29	9.14	0.29	0	0.00	0	0	0	0	0	0	0	33	8.17	0.33	0	0	0	29	16.43	6.86	17	1.17	0.17
	Acanthaluteres sp.	86	149.29	6.14	67	54.50	1.17	17	10.00	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rough Leatherjacket	*Scobinichthys granulatus*	43	25.14	0.43	0	0.00	0	0	0	0	0	0	0	17	3.33	0.17	17	2.33	0.17	0	0	0	0	0	0
Southern Pigmy Leatherjacket	*Brachaluteres jacksonianus*	0	0	0	17	33.83	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leatherjacket	Monacanthidae	43	36.14	0.57	33	9.17	0.33	0	1.00	0	0	0	0	33	2.67	0.33	0	0	0	0	0	0	17	0.50	0.17

Table 1 (Cont.). Frequency of occurrence (F%), mean MaxN and Mean TIV for species recorded with underwater stereo video. Colour key for maximum F% for each species: red (0-25 F%), yellow (26-50 F%), green (51-100 F%)

Common name	Species name	Flinders (*Amphibolis*-Sedimentary)						Balnarring (*Amphibolis*-Sedimentary)						Point Leo (*Amphibolis*-Reef)						Cat Bay (Reef-Algae)					
		Autumn			Spring			Autumn			Spring			Autumn			Spring			Autumn			Spring		
		F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N
Shaw's Cowfish	*Aracana aurita*	0	0	0	0	0.00	0	17	4.17	0.17	0	0	0	17	0.67	0.17	0	0	0	0	0	0	0	0	0
Cowfish	*Aracana* sp.	43	6.71	0.43	50	15.83	0.50	0	0	0	33	19.67	0.33	0	0	0	0	0	0	0	0	0	0	0	0
Spikey Globefish	*Diodon nicthemerus*	0	0	0	0	0.00	0	0	1.67	0	17	2.17	0.17	0	0	0	0	0	0	0	0	0	17	1.33	0.17
Order Teuthida																									
Southern Calamari	*Sepioteuthis australis*	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0	33	17.17	0.33	0	0	0	0	0	0
	Unidentified fish	0	7.00	0	33	7.33	0.33	0	0	0	0	0	0	0	0.83	0	33	2.17	0.33	29	7.57	0.29	0	0	0

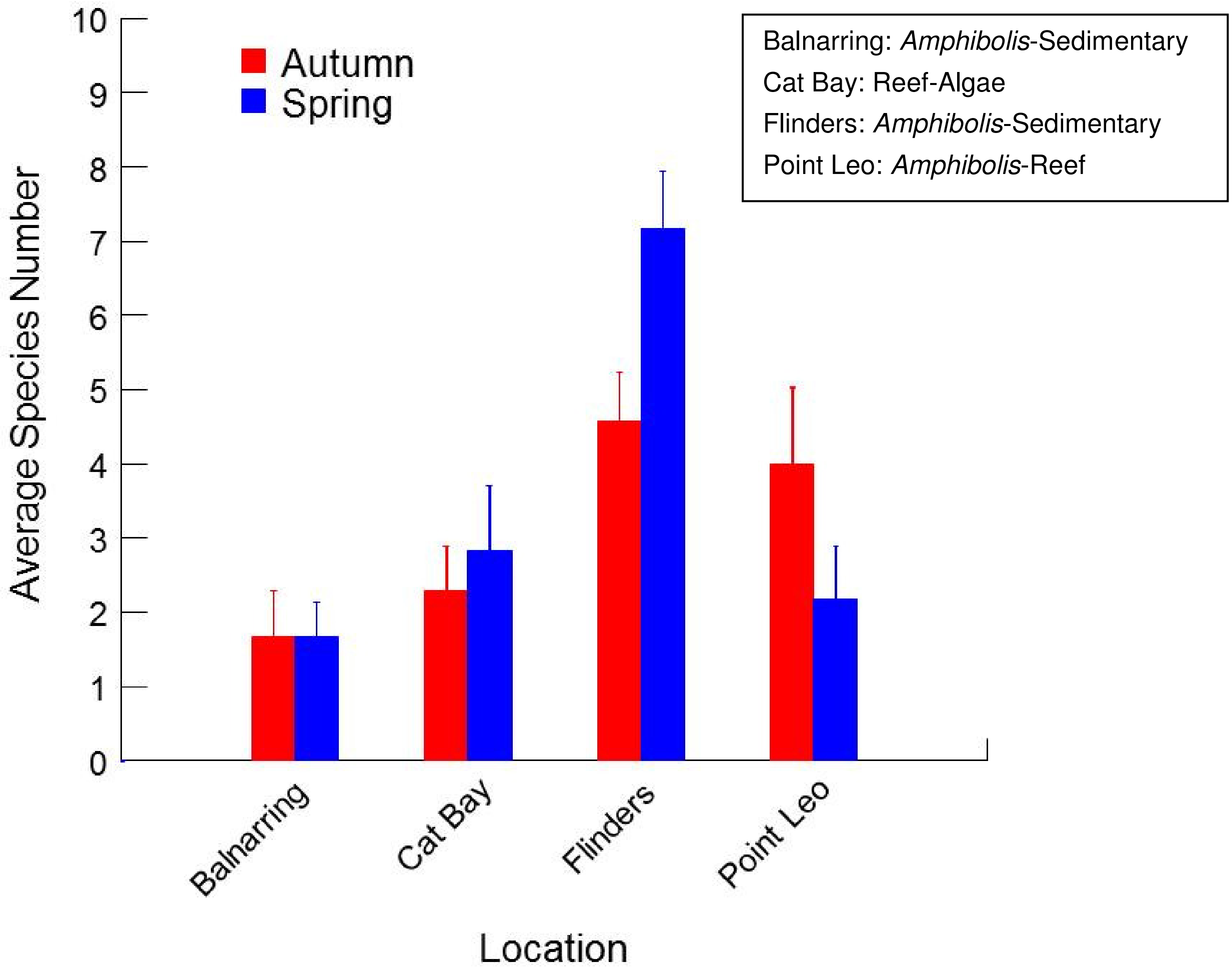
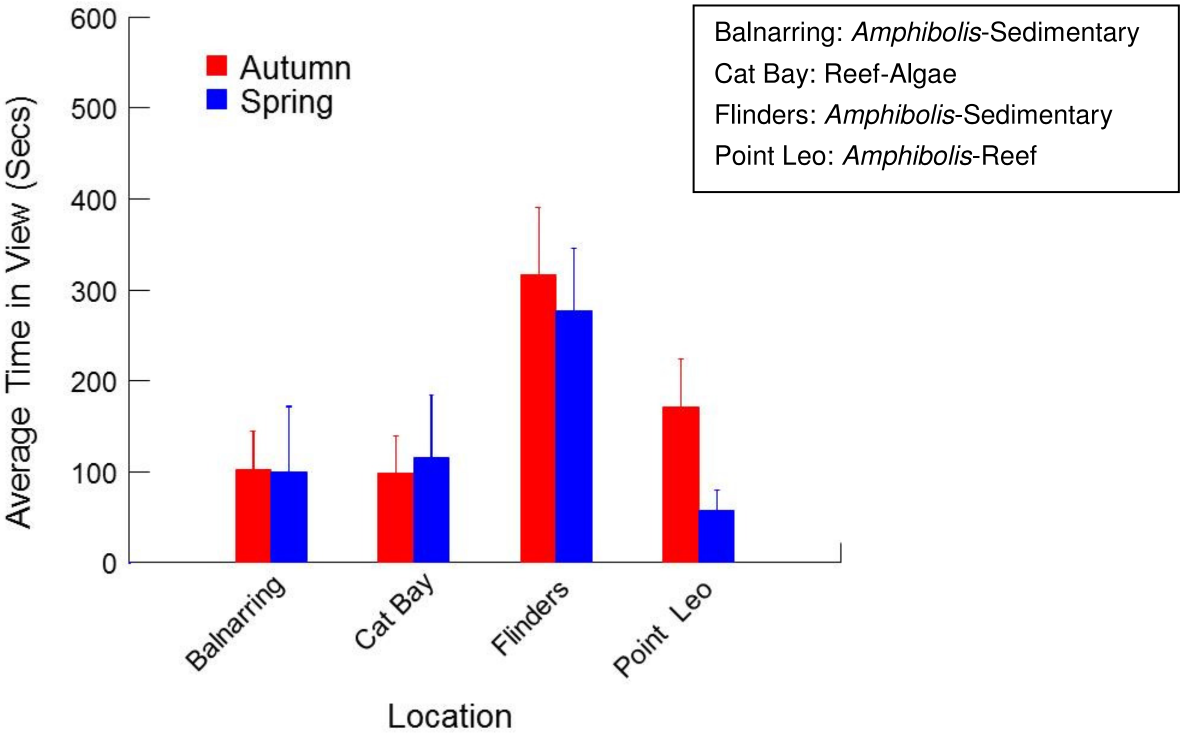


Figure 6. Average (±1 SE) Species Number of fish recorded on underwater stereo video

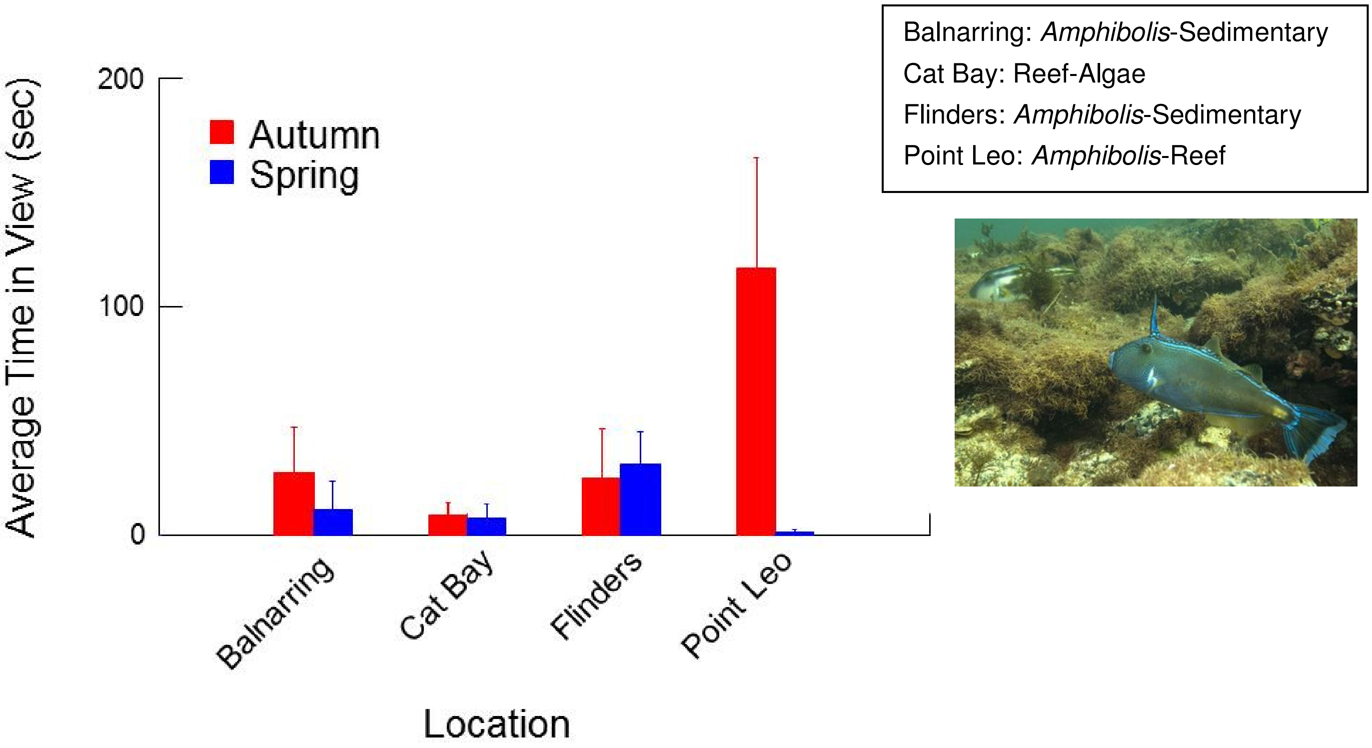
Table 2. ANOVA results for fish recorded on underwater stereo video. Significant *P*-values are in bold

Source	*df*	Species Number		TIV Total Fish		MaxN Total Fish Log (x+1)		*df*	Length Total Fish	
		F	*P*	*F*	*P*	*F*	*P*		*F*	*P*
Season	1	1.097	0.310	0.323	0.578	0.867	0.365	1	10.207	**0.005**
Location	3	11.470	**<0.001**	6.561	**0.004**	2.412	0.105	3	6.841	**0.003**
Season x Location	3	3.799	**0.031**	0.919	0.454	1.486	0.256	3	2.231	0.122
Error	16							15		



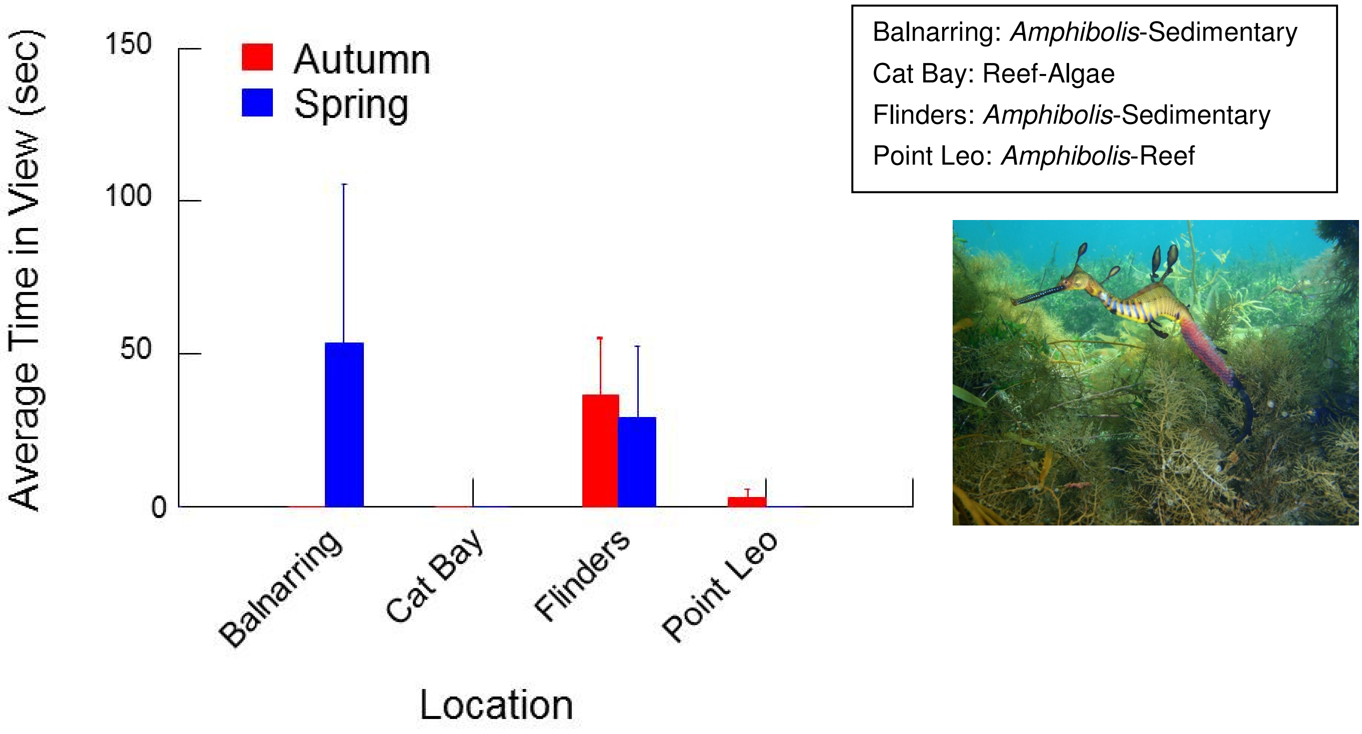
Balnarring: *Amphibolis*-Sedimentary
Cat Bay: Reef-Algae
Flinders: *Amphibolis*-Sedimentary
Point Leo: *Amphibolis*-Reef

Figure 7. Average (±1 SE) Time in View of total fish recorded on underwater stereo video



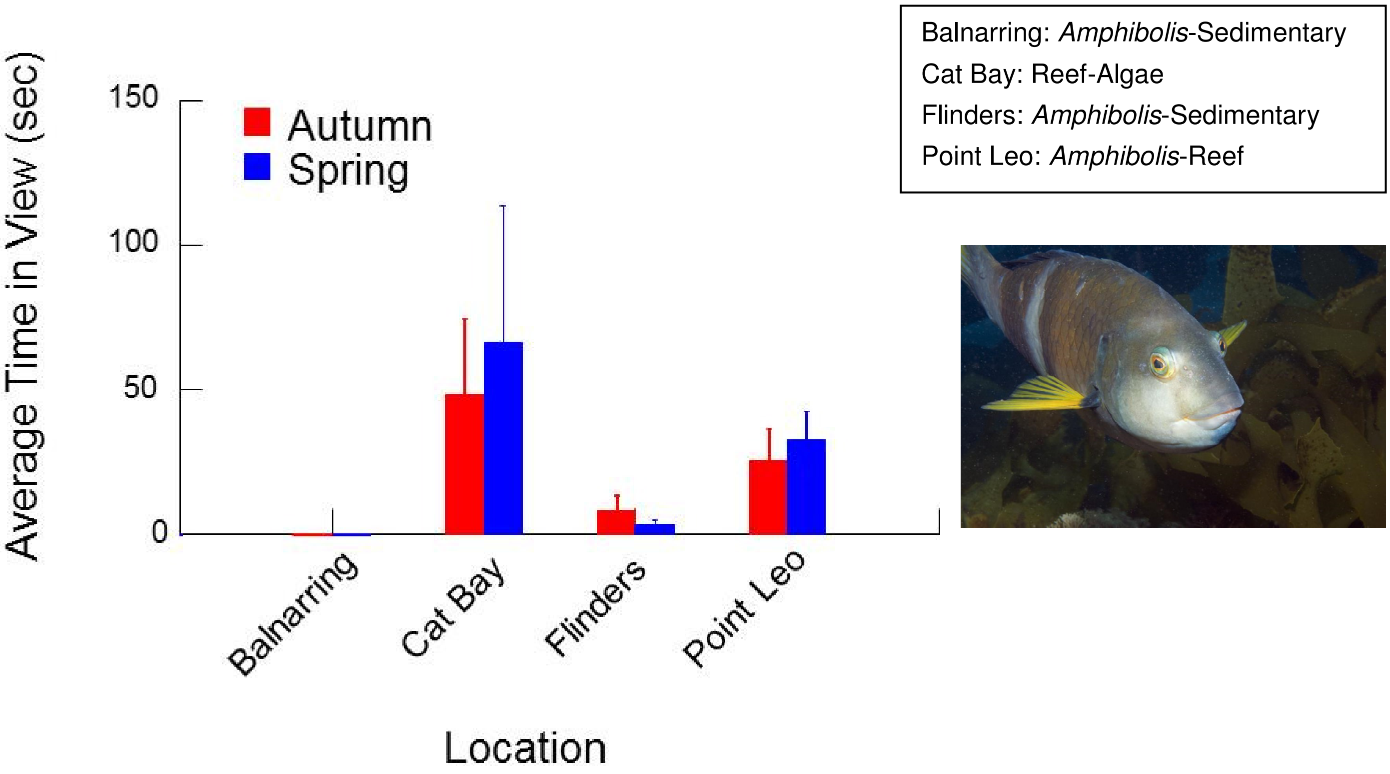
Balnarring: *Amphibolis*-Sedimentary
Cat Bay: Reef-Algae
Flinders: *Amphibolis*-Sedimentary
Point Leo: *Amphibolis*-Reef

Figure 8. Average (±1 SE) Time in View of Sixspine Leatherjacket, *Meuschenia freyceneti*, recorded on underwater stereo video



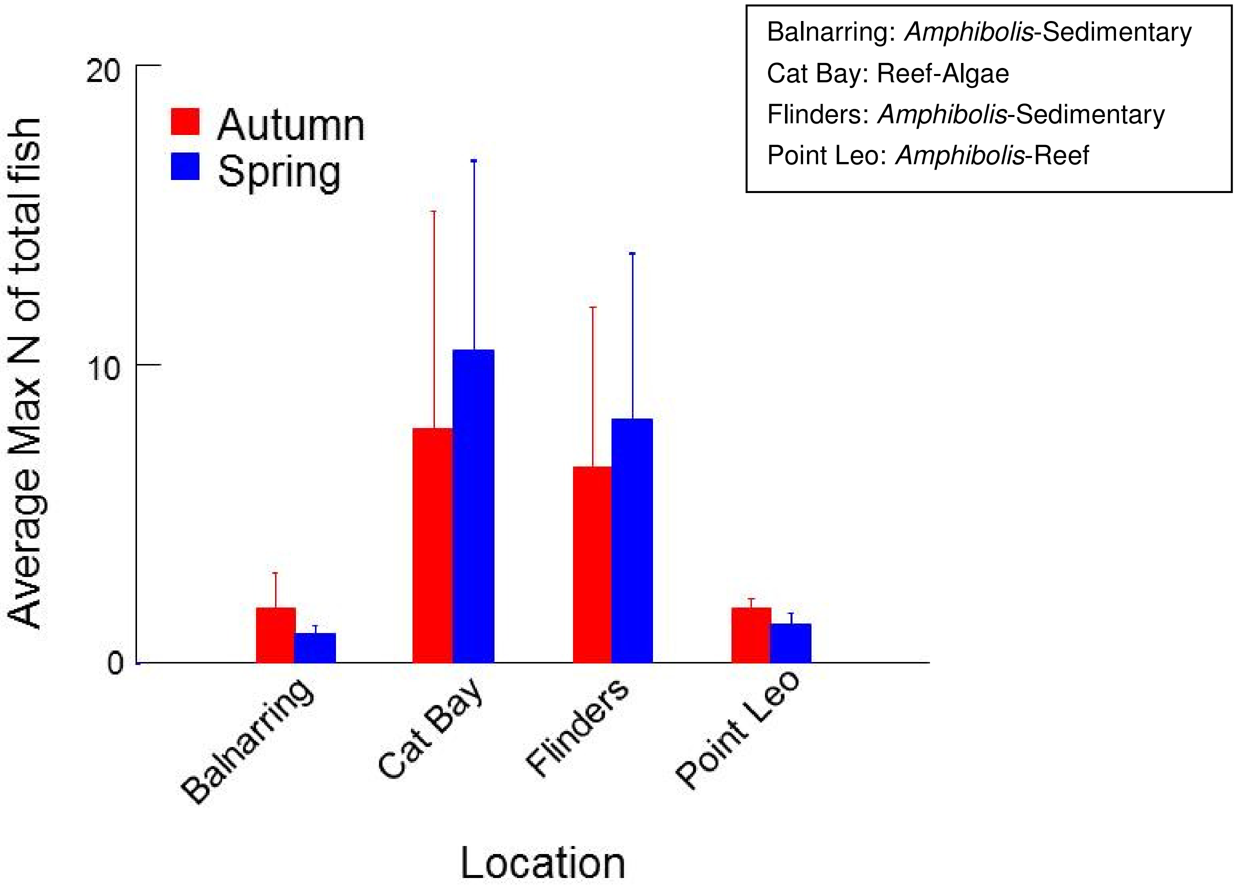
Balnarring: *Amphibolis*-Sedimentary
Cat Bay: Reef-Algae
Flinders: *Amphibolis*-Sedimentary
Point Leo: *Amphibolis*-Reef

Figure 9. Average (±1 SE) Time in View of Weedy Seadragon, *Phyllopteryx taeniolatus*, recorded on underwater stereo video



Balnarring: *Amphibolis*-Sedimentary
Cat Bay: Reef-Algae
Flinders: *Amphibolis*-Sedimentary
Point Leo: *Amphibolis*-Reef

Figure 10. Average (±1 SE) Time in View of Bluethroat Wrasse, *Notolabrus tetricus*, recorded on underwater stereo video



Balnarring: *Amphibolis*-Sedimentary
Cat Bay: Reef-Algae
Flinders: *Amphibolis*-Sedimentary
Point Leo: *Amphibolis*-Reef

Figure 11. Average (±1 SE) MaxN of total fish recorded on underwater stereo video

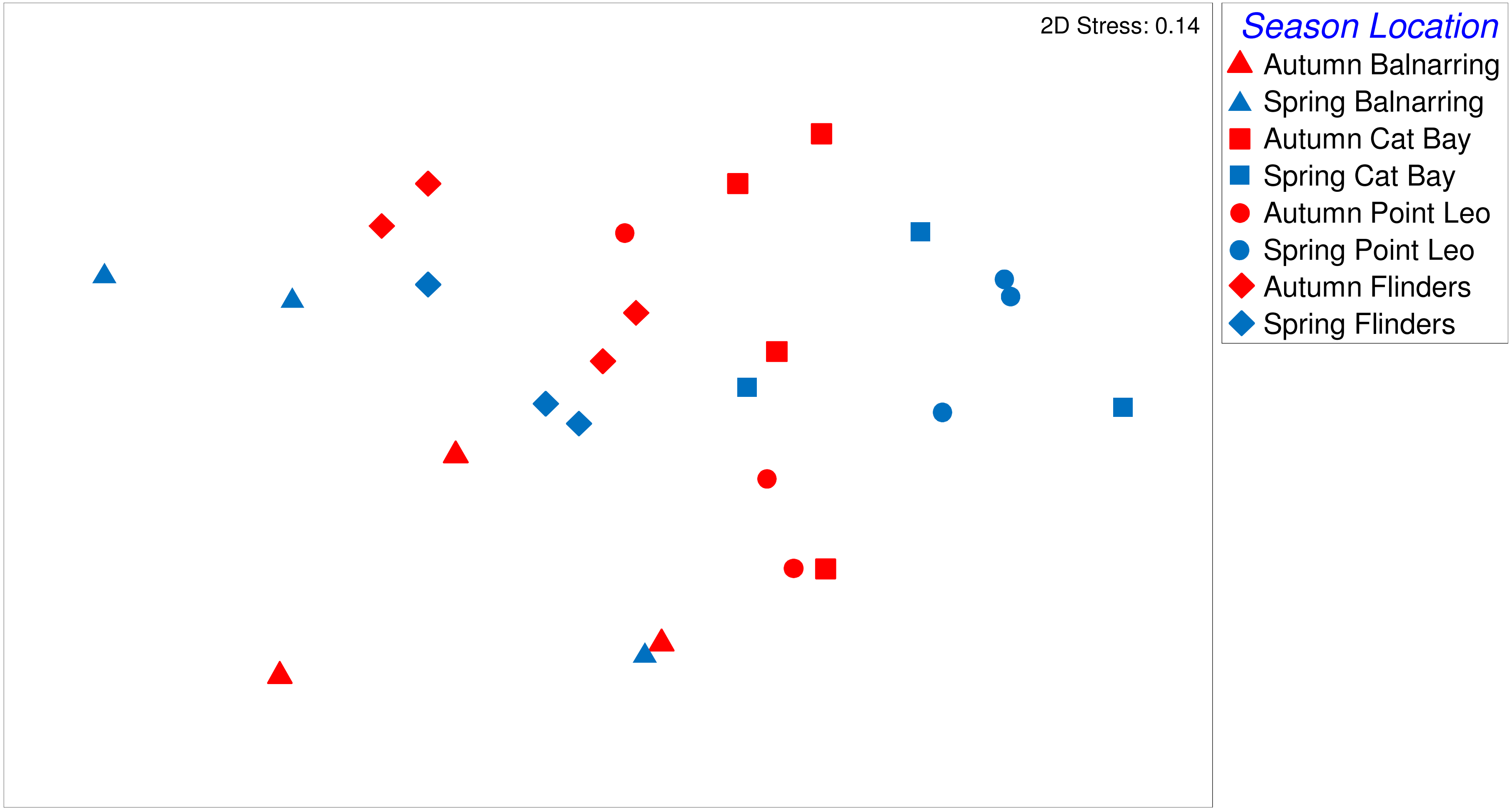


Figure 12. nMDS plot of log(x+1) transformed Time in View data for fish recorded on underwater stereo video

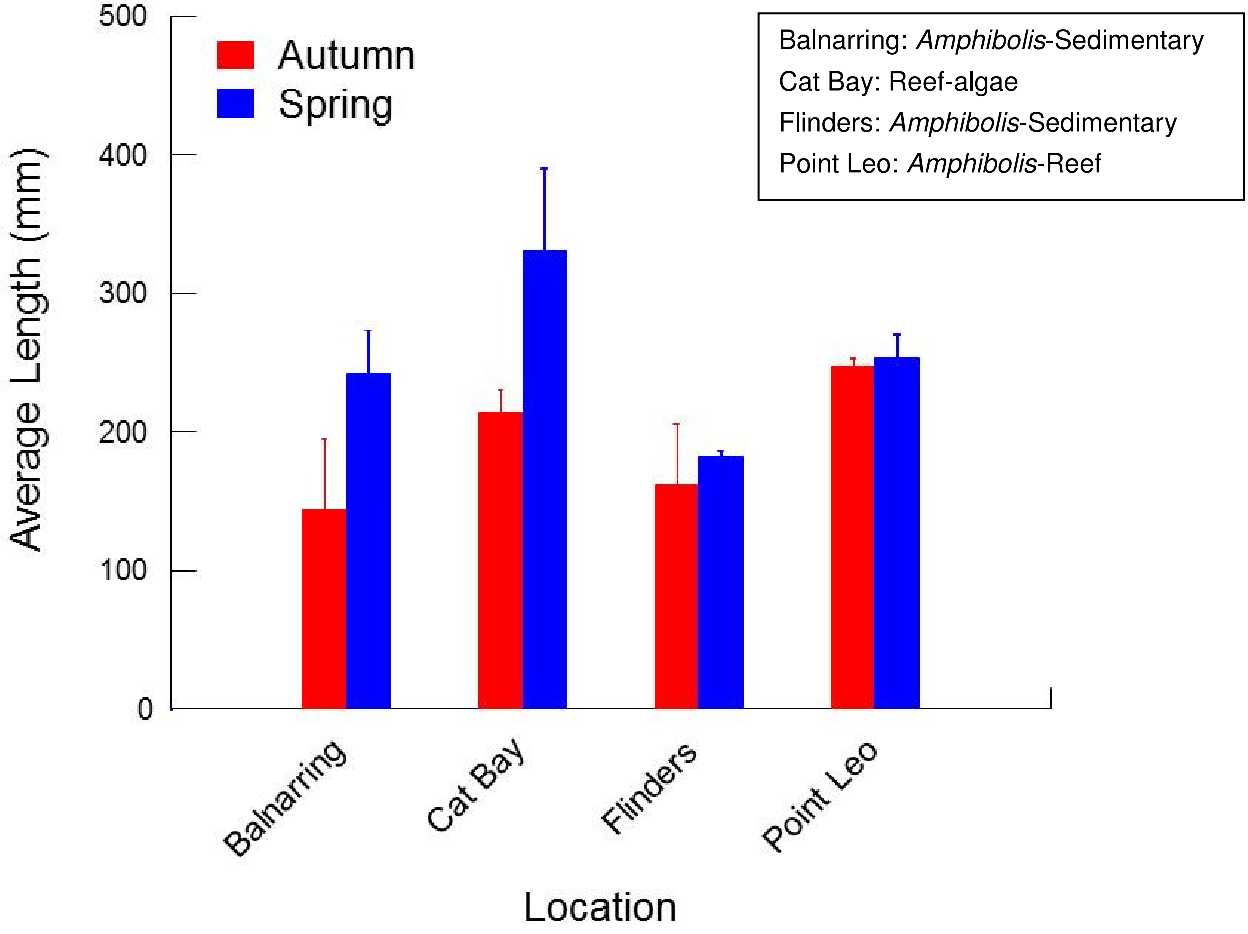


Figure 13. Average (±1 SE) Length of fish recorded on underwater stereo video

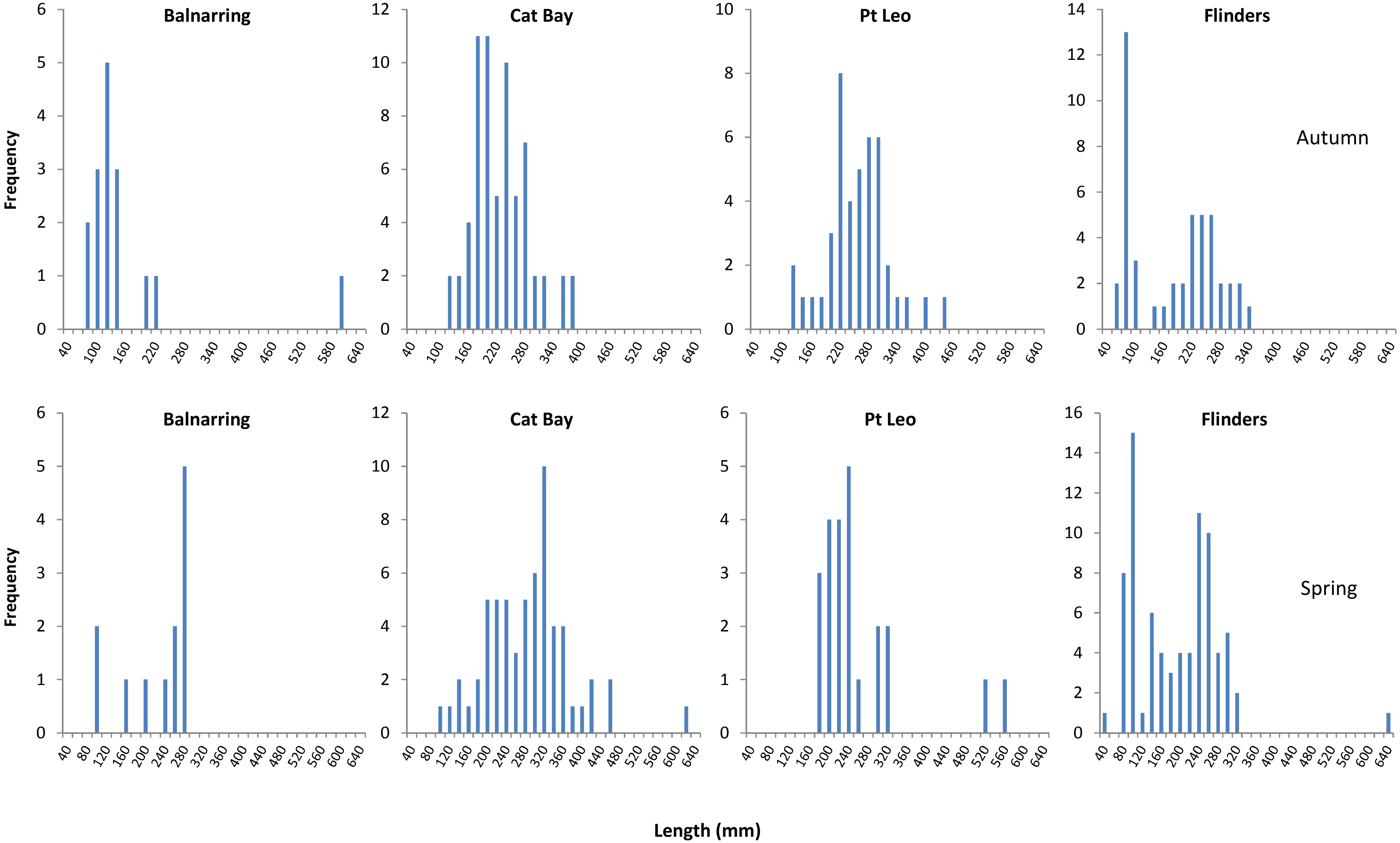


Figure 14. Length-frequency distributions for total fish recorded on underwater stereo video

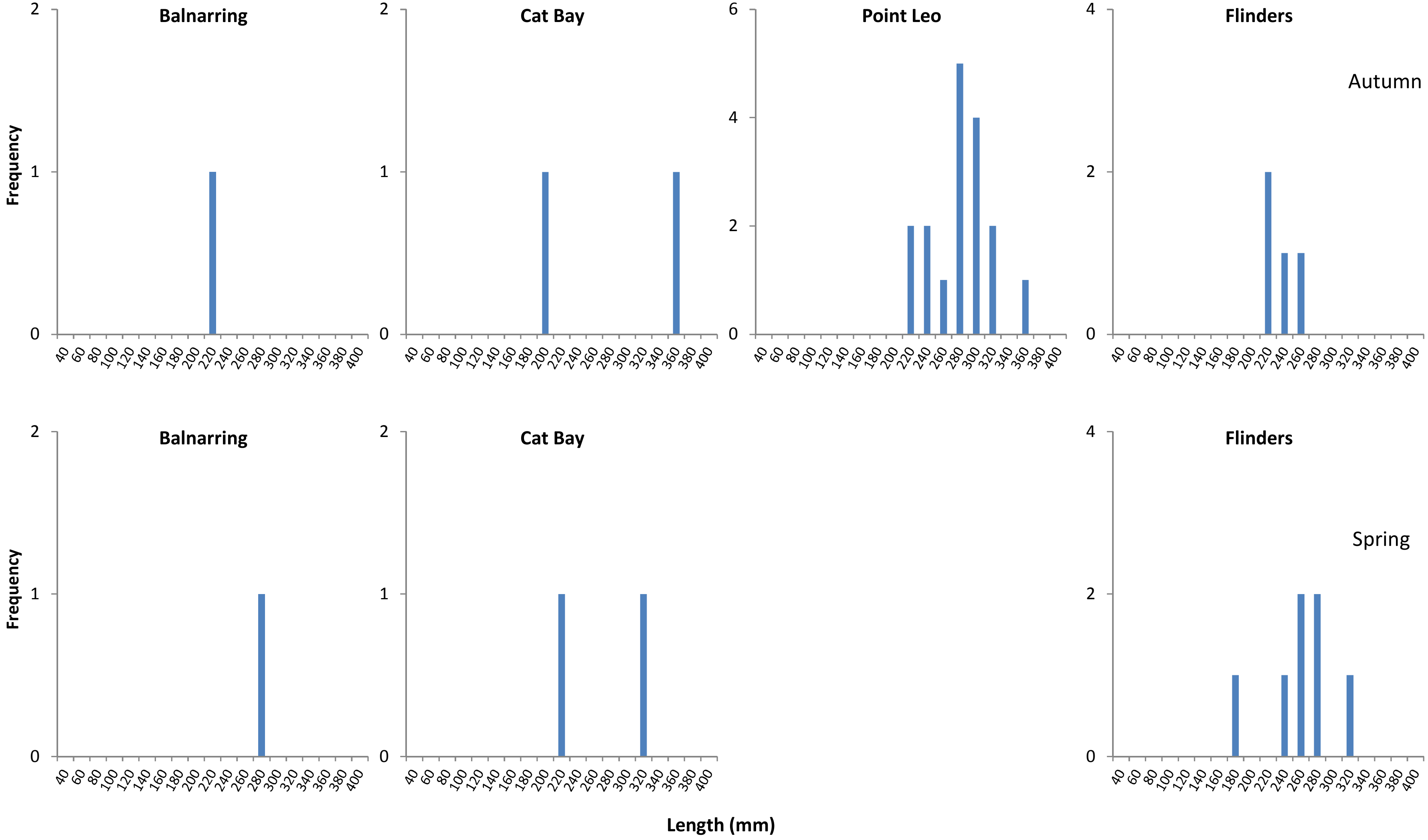


Figure 15. Length-frequency distributions for *Meuschenia freycineti* recorded on underwater stereo video

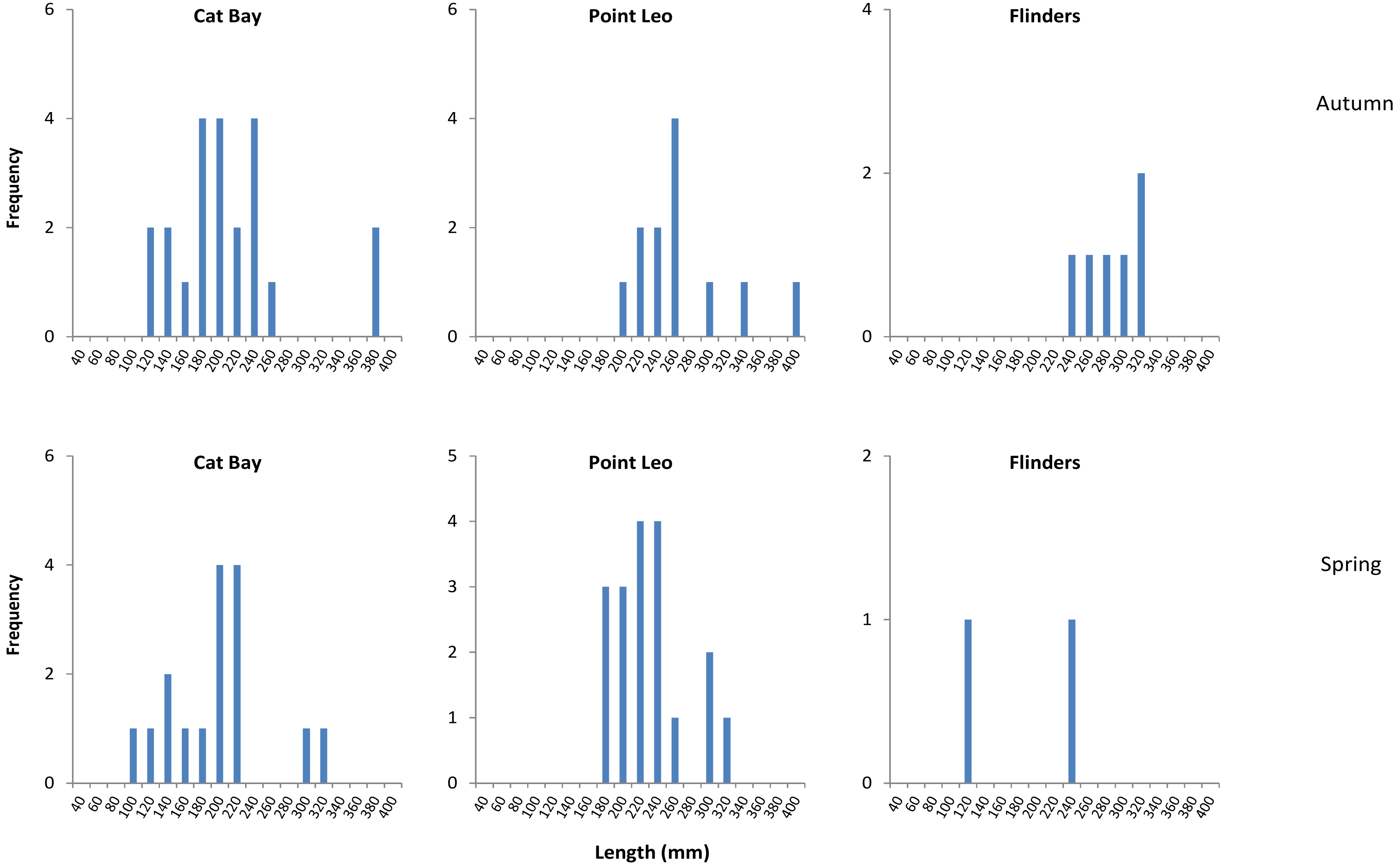


Figure 16. Length-frequency distributions for *Notolabrus tetricus* recorded on underwater stereo video

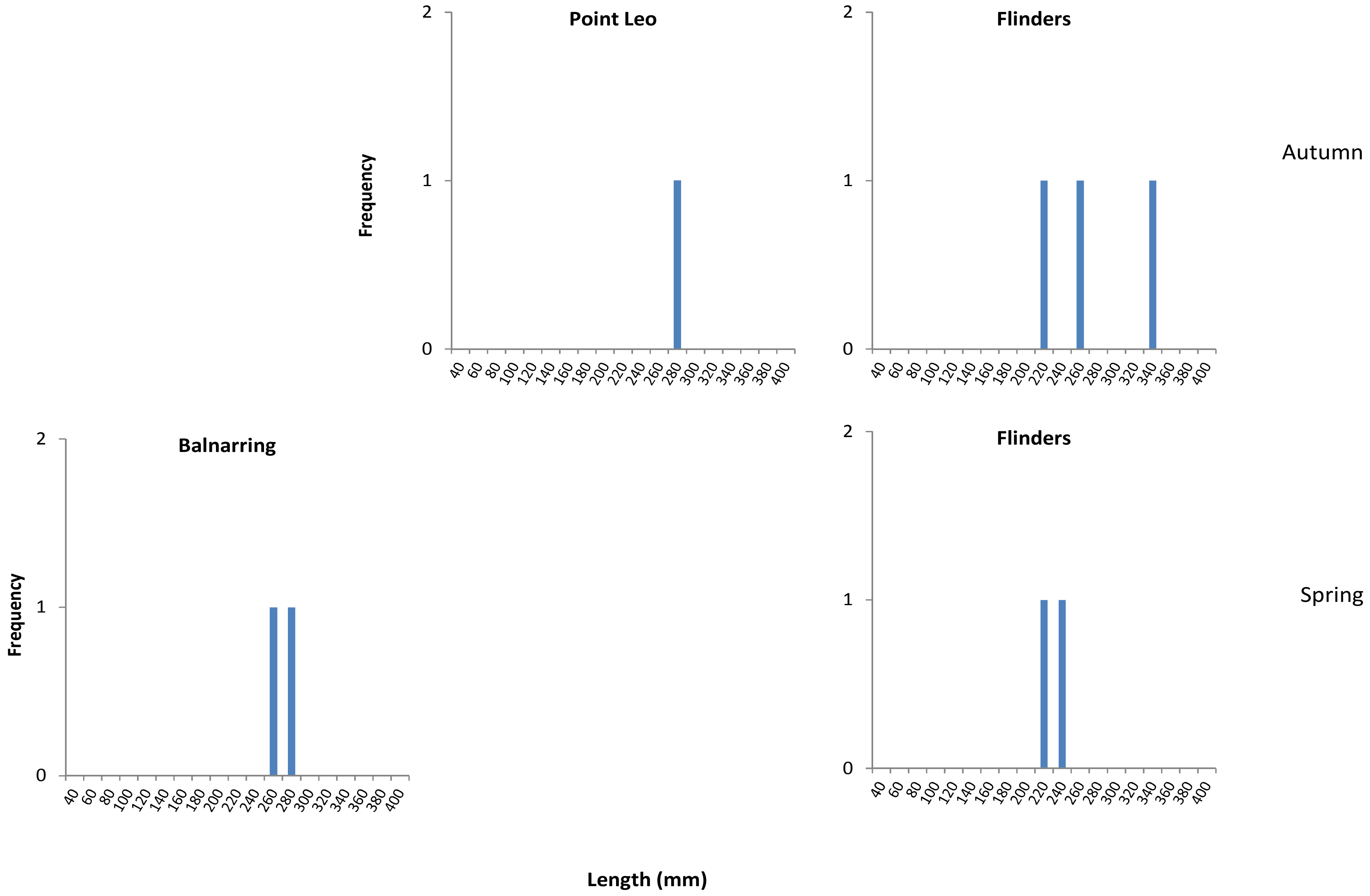


Figure 17. Length-frequency distributions for *Phyllopteryx taeniolatus* recorded on underwater stereo video

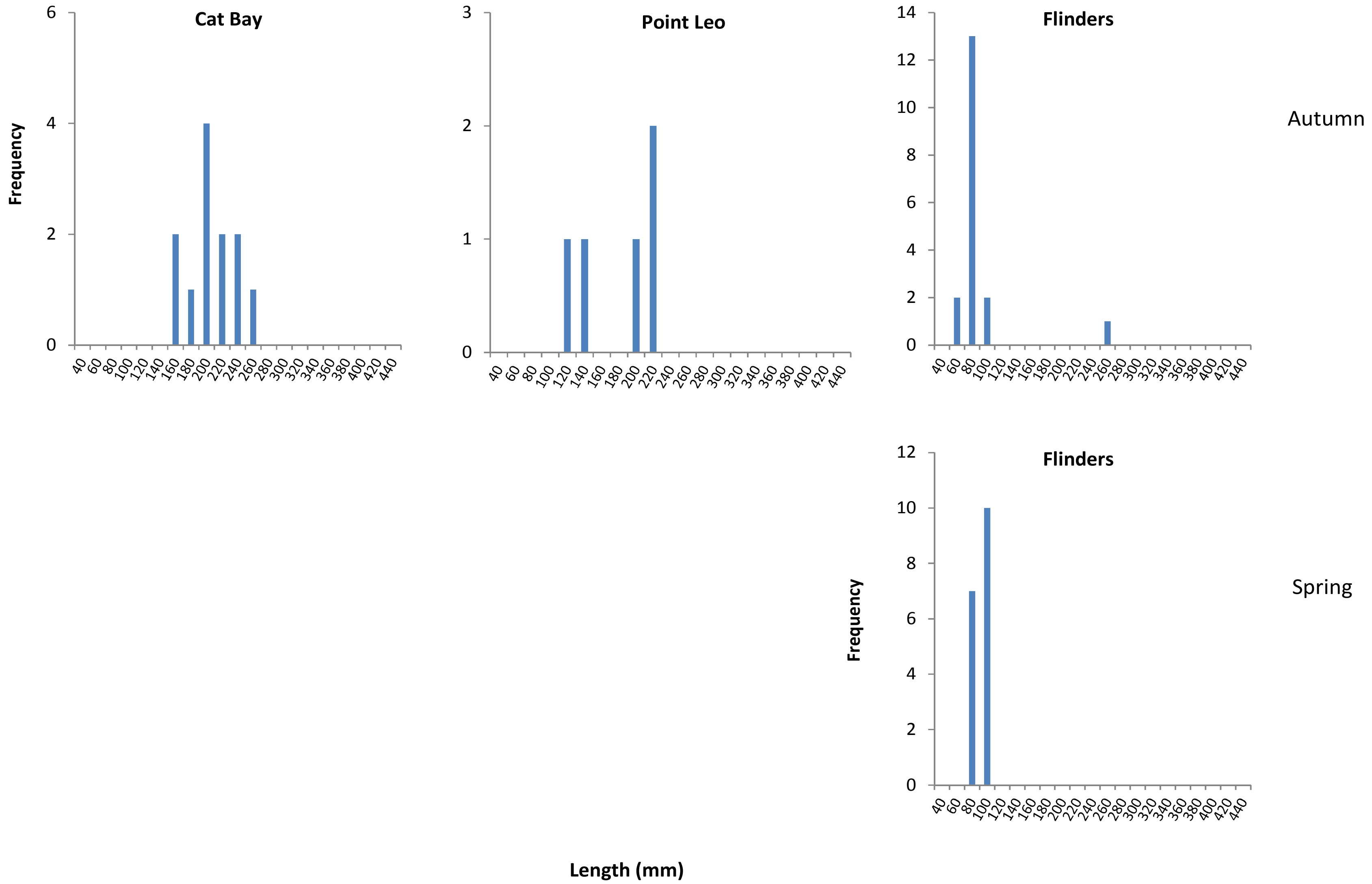


Figure 18. Length-frequency distributions for *Acanthaluteres* sp. recorded on underwater stereo video

Table 3. Frequency of occurrence (F%), mean TiV and mean MaxN for species recorded with underwater stereo video in sedentary invertebrate isolate and rhodolith habitats. Colour key for maximum F% for each species: red (0-25 F%), yellow (26-50 F%), green (51-100 F%)

Common name	Species name	Rhyll Basin (Invertebrate isolates)						Eastern Entrance (Rhodoliths)					
		Spring			Autumn			Spring			Autumn		
		F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N	F%	TiV	Max N
SUBCLASS Elasmobranchii													
Stingaree	Urolophidae	0	0	0	0	0	0	0	0	0	17	3.493	0.17
ORDER Scorpaeniformes													
Flathead	Platycephalidae	33	57.50	0.50	17	15.28	0.17	0	0	0	0	0	0
ORDER Perciformes													
Silverbelly	*Parequula melbournensis*	17	6.17	0.17	0	0	0	0	0	0	0	0	0
Red Mullet	*Upeneichthys vlamingii*	17	1.50	0.17	67	17.94	1.50	17	0.50	0.17	17	4.97	0.17
Australian Salmon	*Arripis* sp.	0	0	0	17	1.18	0.17	0	0	0	0	0	0
Bluethroat Wrasse	*Notolabrus tetricus*	0	0	0	0	0	0	17	1.00	0.17	0	0	0
ORDER Tetraodontiformes													
	Acanthaluteres sp.	0	0	0	33	12.45	0.50	0	0	0	0	0	0
Southern Pigmy Leatherjacket	*Brachaluteres jacksonianus*	0	0	0	17	2.19	0.17	0	0	0	0	0	0
Leatherjacket	Monacanthidae	0	0	0	0	0	0	0	0	0	50	8.20	0.50
Cowfish	*Aracana* sp.	0	0	0	17	1.38	0.17	0	0	0	17	7.13	0.17
Spikey Globefish	*Diodon nicthemerus*	33	5.00	0.33	0	0	0	0	0	0	0	0	0
Smooth toadffish	*Tetractenos glaber*	0	0	0	0	0	0	17	9.83	0.17	17	90.65	0.17
Unidentified fish		0	0	0	17	2.01	0.17	0	0	0	0	0	0

Mini Otter Trawl

A total of 36 fish taxa were recorded in the Mini Otter Trawl sampling (Table 4). The number of taxa was very similar to that recorded by underwater stereo video; however, only 11 taxa were recorded in both sampling programs (Table 1,4). The taxa with the highest overall abundances were the leatherjackets, *Acanthaluteres* sp., the Cobbler, *Gymnapistes marmoratus*, the Little Weed Whiting, *Neoodax balteatus*, the Spotted Pipefish, *Stigmatopora argus*, and the Grass Whiting, *Haletta semifasciata* (Table 4). Four taxa were recorded from all combinations of location and season, the Rough Leatherjacket, *Scobinichthys granulatus,* the Southern Pigmy Leatherjacket, *Brachaluteres jacksonianus*, the Ornate Cowfish, *Aracana ornata*, and the Southern Cardinalfish, *Vincentia conspersa* (Table 4). Important commercial and recreational fishing species that were recorded from the sampling included the Rock Flathead, *Platycephalus laevigatus*, and the Sand Flathead, *Platycephalus bassensis*.

Species richness compared across three locations over two seasons showed a highly significant difference amongst locations but no difference between seasons (Table 5, Fig. 19). Tukey's post-hoc test (P<0.05) showed that Hastings had significantly lower species richness than the other two locations (Table 5). When species richness was compared across four locations in autumn, there was a significant difference among locations (Table 6, Fig. 19), with Hastings significantly lower than Coronet Bay (Tukey's post-hoc test, P<0.05). Abundance of total fish compared across three locations over two seasons also showed a highly significant difference amongst locations but no difference between seasons (Table 5, Fig. 20). Tukey's post-hoc test (P<0.05) showed that Coronet Bay had significantly higher abundance than Loelia Shoal, which in turn had a significantly higher abundance than Hastings (Table 5). When abundance was compared across four locations in autumn, there was a significant difference among locations (Table 6, Fig. 20), with Hastings significantly lower than Coronet Bay (Tukey's post-hoc test, P<0.05).

The patterns of abundance for the most commonly recorded species are shown in Figures 21 to 25. For *Acanthaluteres* sp., abundance was generally highest at the Coronet Bay location and lowest at the Hastings location, and was also higher in autumn (Fig. 21). In autumn, abundance at the Hastings-SG location was similar to Loelia Shoal and intermediate between Coronet Bay and Hastings (Fig. 21). The pattern for *G. marmoratus* was similar to *Acanthaluteres* sp. excepting that abundances were higher in spring than autumn, and the species was not recorded at all from the Hastings location (Fig. 22). The abundance at Hastings-SG was similar to the Loelia Shoal location in autumn (Fig. 22). The pattern for *N. balteatus* again showed highest abundance at Coronet Bay, intermediate at Loelia Shoal, and very low abundance at Hastings (Fig. 23). Like *G. marmoratus*, abundances were higher in spring (Fig. 23). In autumn, abundance of *N. balteatus* at Hastings-SG was higher similar to Coronet Bay and higher than the other locations (Fig. 23). The pattern for *S. argus* was quite different to the other species (Fig. 24); abundances were similar for Coronet Bay and Loelia Shoal with most recorded in spring, but the species was not recorded at Hastings (Fig. 24). In autumn, abundances at the Hastings-SG location were much higher than any other site (Fig. 24). The pattern for *H. semifasciata* was slightly different again with highest abundance at Coronet Bay, low abundance at Hastings and very low abundance at Loelia Shoal

(Fig. 25). In autumn, abundance at Hastings-SG was similar to Coronet Bay and much higher than the other two sites (Fig. 25).

Analysis of the fish community using nMDS showed a major separation between the Hastings location and the other locations (Fig. 26). There were also some seasonal differences evident, most notably at the Loelia Shoal location (Fig. 26). The community structure at the Hastings-SG location in autumn was very similar to the Coronet Bay location and well separated from the Hastings location (Fig. 26).

Two-way ANOSIM of three locations over two seasons showed a significant difference in community structure amongst locations (Global R: 0.568, P=0.001) and between seasons (Global R: 0.365, P=0.004). Pairwise tests indicated that significant differences in community structure occurred amongst all locations (P<0.05). SIMPER analysis indicated that *N. balteatus* (14.63%), *A. ornata* (11.87%) and *G. marmoratus* (11.32%) contributed most to the difference between Hastings and Loelia Shoal; *G. marmoratus* (11.43%), Wood's Siphonfish, *Siphamia cephalotes* (10.42%) and *N. balteatus* (10.20%) contributed most to the difference between Hastings and Coronet Bay; and, *H. semifasciata* (10.43%) contributed most to the difference between Coronet Bay and Loelia Shoal. In terms of the seasonal comparison, *B. jacksonianus* (12.74%) and *A. ornata* (10.46%), contributed most to the difference in community structure between seasons; both were more abundant in autumn.

One-way ANOSIM of four locations in autumn also showed a significant difference in community structure amongst locations (Global R: 0.556, P=0.001). Pairwise tests indicated that significant differences in community structure occurred between Hastings and all other locations, and also between Hastings-SG and Loelia Shoal (P<0.05). SIMPER analysis indicated that *S. argus* (14.90%), *N. balteatus* (13.17%) and *H. semifasciata* (12.93%) contributed most to the difference between Hastings and Hastings-SG; *N. balteatus* (15.31%) and *A. ornata* (14.36%) contributed most to the difference between Hastings and Loelia Shoal; and, *H. semifasciata* (16.15%), *S. argus* (14.07%) and *B. jacksonianus* (10.78%) contributed most to the difference between Hastings-SG and Loelia Shoal. No species contributed more than 10% of the difference in community structure between Hastings and Coronet Bay.

The mean lengths of fish recorded by mini otter trawl for three locations over two seasons were significantly different between seasons but not amongst locations (Table 5), with greater mean length of fish in spring compared with autumn (Fig. 27). For the comparison of four locations in autumn, there was a significant difference amongst locations (Table 6), and Tukeys post-hoc test (P<0.05) indicated that this was due to greater mean length of fish at Hastings-SG compared to the other locations (Fig. 27).

Length-frequency distributions of total fish showed that in spring there was a uni-modal distribution of fish lengths at the three locations with a peak around 100 mm (but also including 60 – 80 mm size classes at Coronet Bay) (Fig. 28). In autumn, the length-frequency distributions at these locations included a greater proportion of small (40 – 60 mm) individuals (Fig. 28). In autumn, the length-frequency distribution of fish at the Hastings-SG location had a greater proportion of larger (80 – 200 mm) fish than the other locations (Fig. 28). The length-frequency distribution of *S. argus* shows that many of the larger fish (120-180 mm) collected at Coronet Bay and Loelia Shoal in spring, and at Hastings-SG in autumn, were individuals of this species (Fig. 29). The size-frequency distribution of *N. balteatus* was relatively consistent amongst sites and between seasons, ranging from approximately 80 – 180 mm (Fig. 30), as was the distribution for *Acanthaluteres* sp., ranging from approximately 40 to 120 mm (Fig. 31). The size-frequency distribution of *H. semifasciata* showed a greater modal length for Coronet Bay in spring relative to autumn (Fig. 32), and a bi-modal distribution for Hastings-SG in autumn with modes at approximately 80-100 mm and 180-200 mm (Fig. 32).

Table 4. Frequency of occurrence (F%) and mean abundance for species collected in the mini otter trawl. Colour key for maximum F% for each species: red (0-25 F%), yellow (26-50 F%), green (51-100 F%)

Common name	Species name	Coronet Bay (*Caulerpa*)				Leolia Shoal (*Caulerpa*)				Hastings (Invertebrate isolates)				Hastings (*Zostera* seagrass)	
		Spring		Autumn		Spring		Autumn		Spring		Autumn		Autumn	
		F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}
SUBCLASS Elasmobranchii															
Banded Stingaree	*Urolophus cruciatus*	0	0.00	25	0.25	0	0.00	25	0.25	0	0.00	0	0.00	0	0.00
Stingaree	Urolophidae	0	0.00	0	0.00	25	0.25	0	0.00	0	0.00	0	0.00	0	0.00
Thornback Skate	*Dipturus lemprieri*	0	0.00	0	0.00	0	0.00	25	0.25	0	0.00	0	0.00	0	0.00
ORDER Gasterosteiformes															
Widebody Pipefish	*Stigmatopora nigra*	0	0.00	0	0.00	0	0.00	50	0.75	17	0.17	25	0.50	0	0.00
Spotted Pipefish	*Stigmatopora argus*	100	6.50	75	1.25	100	5.75	50	0.50	0	0.00	0	0.00	100	19.50
Halfbanded Pipefish	*Mitotichthys semistriatus*	25	0.25	0	0.00	0	0.00	25	0.25	0	0.00	0	0.00	50	1.25
Port Phillip Pipefish	*Vanacampus phillipi*	25	0.25	25	0.50	0	0.00	25	0.50	0	0.00	0	0.00	25	0.25
Shorthead Seahorse	*Hippocampus breviceps*	25	0.25	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ORDER Scorpaeniformes															
Little Gurnard Perch	*Maxillicosta scabriceps*	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	25	0.25
Common Gurnard Perch	*Neosebastes scorpaenoides*	0	0.00	0	0.00	25	0.25	0	0.00	0	0.00	0	0.00	0	0.00
Cobbler	*Gymnapistes marmoratus*	100	23.25	75	14.25	100	9.75	75	1.50	0	0.00	0	0.00	100	3.25
Southern Velvetfish	*Aploactisoma milesii*	50	1.75	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Spiny Gurnard	*Lepidotrigla papilio*	0	0.00	25	0.25	0	0.00	0	0.00	0	0.00	25	0.25	0	0.00
Southern Sand Flathead	*Platycephalus bassensis*	0	0.00	25	0.25	0	0.00	25	0.25	0	0.00	0	0.00	0	0.00
Rock Flathead	*Platycephalus laevigatus*	50	0.75	75	1.00	25	0.25	0	0.00	0	0.00	0	0.00	25	0.25

Table 4 (Cont.). Frequency of occurrence (F%), mean abundance for species collected in the mini otter trawl. Colour key for maximum F% for each species: red (0-25 F%), yellow (26-50 F%), green (51-100 F%)

Common name	Species name	Coronet Bay (*Caulerpa*)				Leolia Shoal (*Caulerpa*)				Hastings (Invertebrate isolates)				Hastings (*Zostera* seagrass)	
		Spring		Autumn		Spring		Autumn		Spring		Autumn		Autumn	
		F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}
ORDER Perciformes															
Wood's Siphonfish	*Siphamia cephalotes*	100	19.50	100	3.75	75	4.00	25	1.25	0	0.00	0	0.00	50	0.75
Southern Cardinalfish	*Vincentia conspersa*	100	9.00	100	10.25	100	2.50	25	1.25	17	0.33	25	0.25	50	0.50
Red Mullet	*Upeneichthys vlamingii*	50	0.50	75	1.50	25	0.25	75	1.50	0	0.00	50	0.75	25	0.25
Old Wife	*Enoplosus armatus*	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	25	0.25
Little Weed Whiting	*Neoodax balteatus*	100	14.50	75	9.75	100	7.75	100	5.50	33	0.33	0	0.00	100	8.75
Grass Whiting	*Haletta semifasciata*	75	5.75	100	12.75	25	0.25	0	0.00	17	0.50	25	1.00	100	12.25
Crested Weedfish	*Cristiceps australis*	25	0.25	25	0.25	50	1.00	25	0.25	0	0.00	0	0.00	0	0.00
Adelaide Weedfish	*Heteroclinus adelaide*	50	0.50	50	0.50	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Common Stinkfish	*Foetorepus calauropomus*	0	0.00	0	0.00	0	0.00	0	0.00	17	0.17	0	0.00	0	0.00
Sculptured Goby	*Callogobius mucosus*	25	0.50	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sailfin Goby	*Nesogobius pulchellus*	0	0.00	25	0.25	0	0.00	50	0.50	0	0.00	25	0.25	0	0.00
Snook	*Sphyraena novaehollandiae*	0	0.00	25	0.25	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ORDER Pleuronectiformes															
Mueller's Flounder	*Arnoglossus muelleri*	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	25	0.25	0	0.00

Table 4 (Cont.). Frequency of occurrence (F%), mean abundance for species collected in the mini otter trawl. Colour key for maximum F% for each species: red (0-25 F%), yellow (26-50 F%), green (51-100 F%)

Common name	Species name	Coronet Bay (*Caulerpa*)				Leolia Spit (*Caulerpa*)				Hastings (Invertebrate isolates)				Hastings (*Zostera* seagrass)	
		Spring		Autumn		Spring		Autumn		Spring		Autumn		Autumn	
		F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}	F%	Abundance No. haul^{-1}
ORDER Tetraodontiformes															
Sixspine Leatherjacket	*Meuschenia freycineti*	100	2.25	75	3.00	50	0.75	50	0.75	0	0.00	25	0.25	100	3.00
Bridled Leatherjacket	*Acanthaluteres spilomelanurus*	25	0.25	0	0.00	75	1.25	0	0.00	17	0.17	0	0.00	0	0.00
	Acanthaluteres sp.	100	12.50	100	18.75	100	2.00	100	7.50	17	0.17	75	3.50	100	8.75
Rough Leatherjacket	*Scobinichthys granulatus*	100	1.75	100	12.25	25	0.25	100	2.00	33	0.50	25	0.25	75	2.75
Southern Pigmy Leatherjacket	*Brachaluteres jacksonianus*	50	1.00	100	15.25	25	0.25	100	10.00	33	0.33	75	2.00	50	0.75
Leatherjacket	Monacanthidae	50	1.00	25	0.25	25	0.25	0	0.00	0	0.00	0	0.00	0	0.00
Ornate Cowfish	*Aracana ornata*	50	1.75	100	3.50	25	0.25	75	1.25	50	3.50	100	10.50	75	3.25
Spikey Globefish	*Diodon nicthemerus*	75	5.00	0	0.00	50	0.50	25	0.25	17	0.17	25	0.25	0	0.00

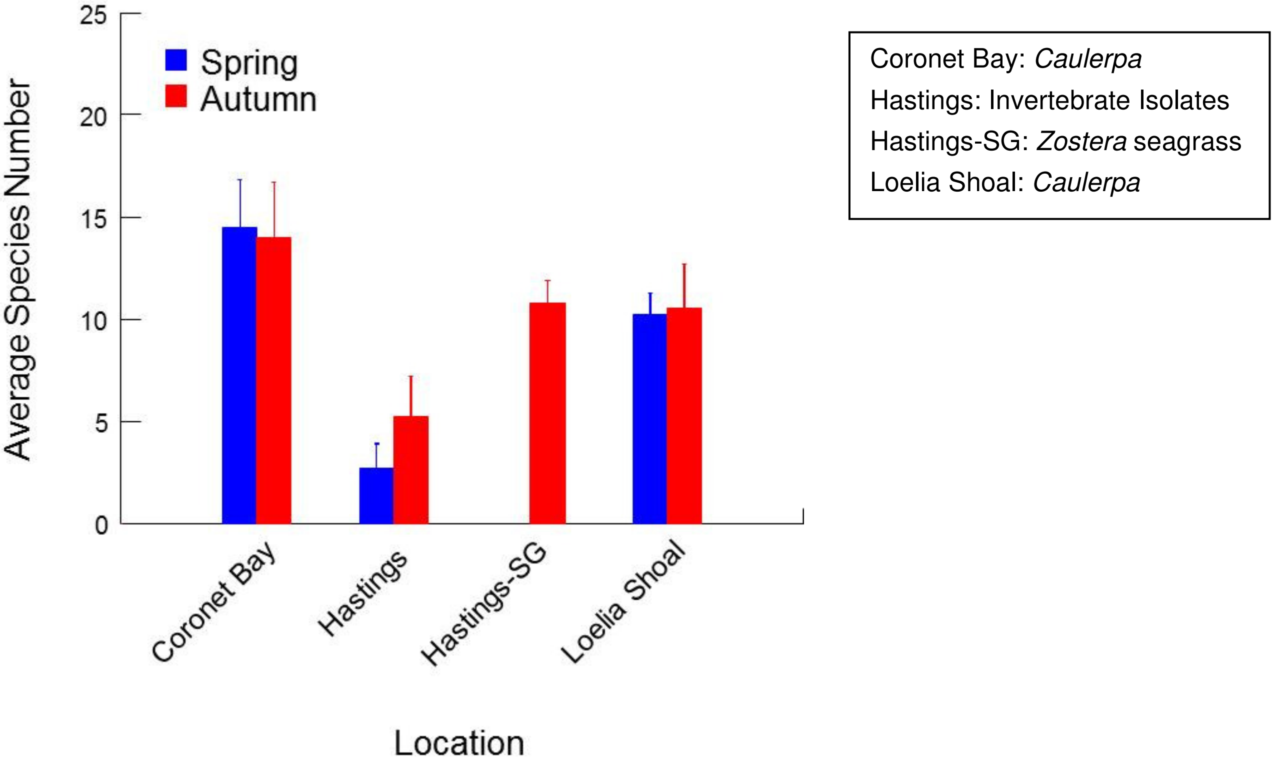


Figure 19. Average (±1 SE) species number of fish collected by mini otter trawl. NB Hastings-SG location was only sampled in autumn

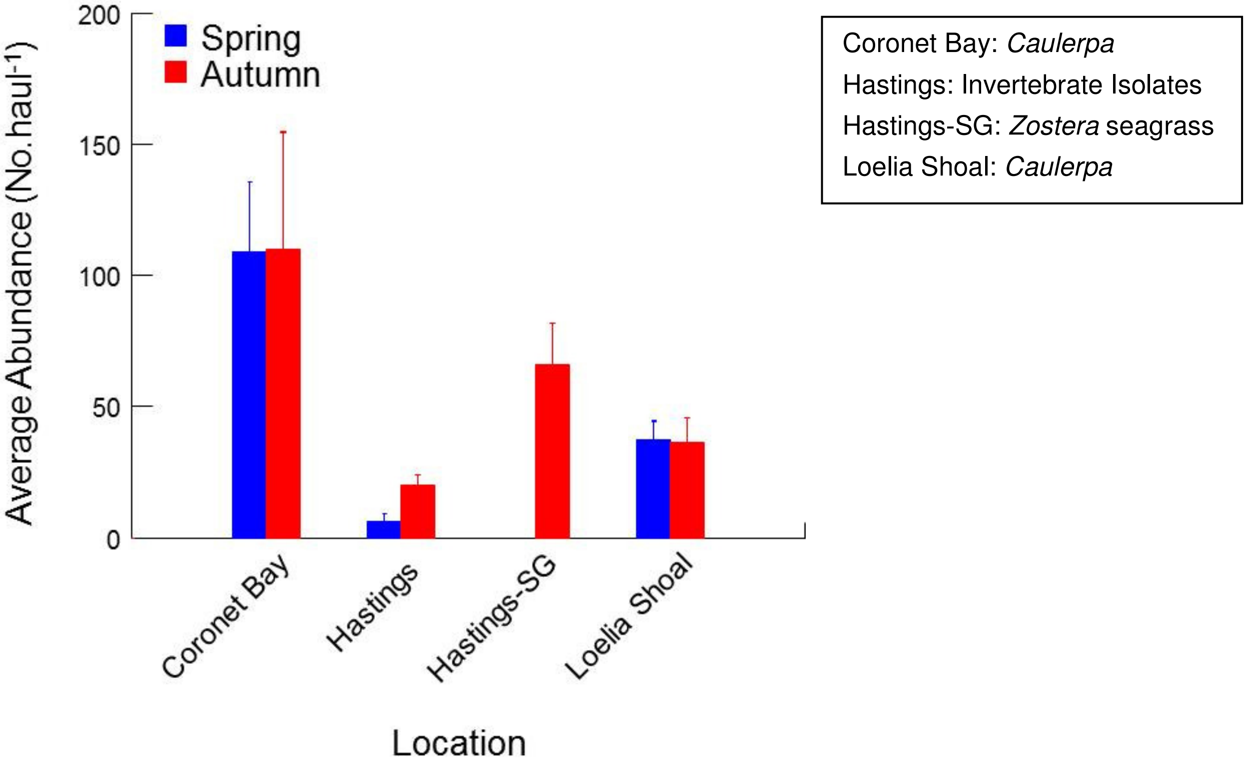


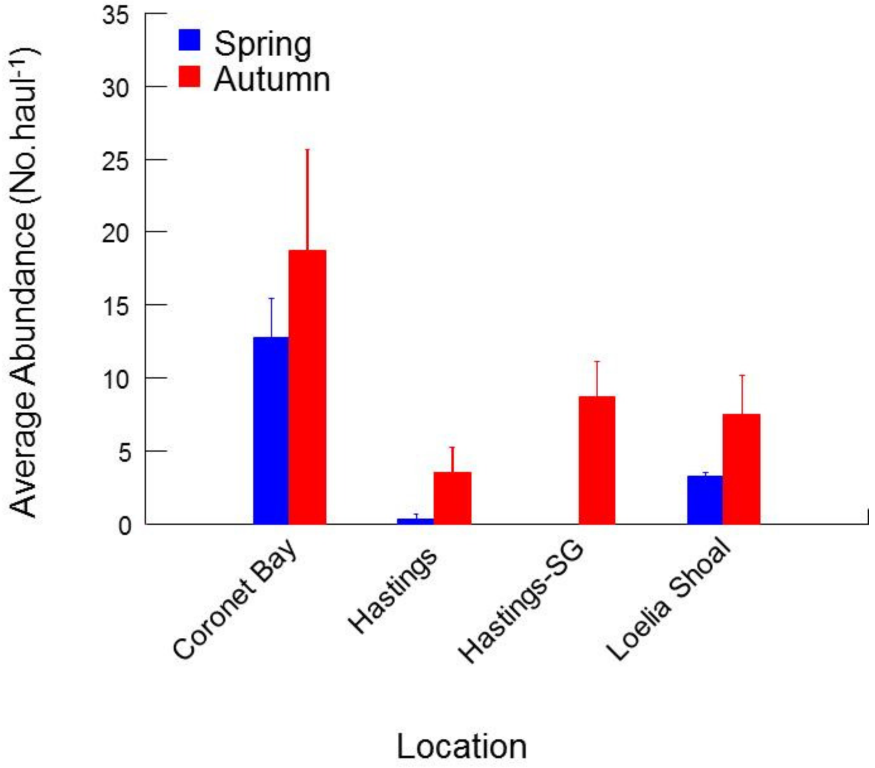
Figure 20. Average (±1 SE) abundance of total fish collected by mini otter trawl. NB Hastings-SG location was only sampled in autumn

Table 5. ANOVA results for fish collected by mini otter trawl at three locations over two seasons. Significant *P*-values are in bold

Source	df	Species Number		Total Fish		Total Fish Length	
		F	*P*	*F*	*P*	*F*	*P*
Season	1	0.165	0.689	1.091	0.310	22.912	**<0.001**
Location	2	16.471	**<0.001**	25.993	**<0.001**	0.494	0.618
Season x Location	2	0.267	0.769	2.562	0.105	1.235	0.314
Error	18						

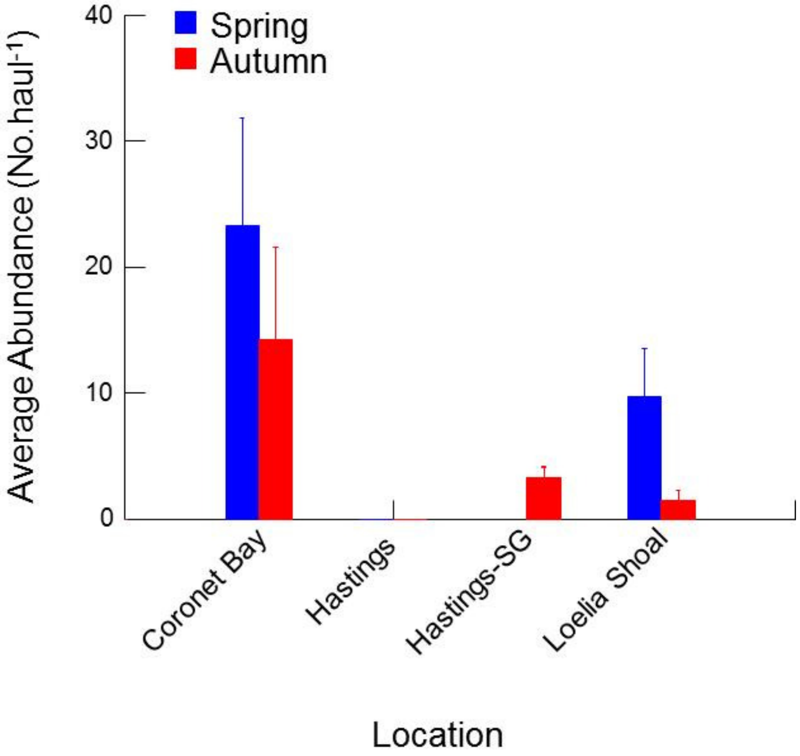
Table 6. ANOVA results for fish collected by mini otter trawl at four locations in autumn. Significant *P*-values are in bold

Source	df	Species Number		Total Fish		Total Fish Length	
		F	*P*	*F*	*P*	*F*	*P*
Location	3	4.294	**0.028**	4.690	**0.022**	13.75	**<0.001**
Error	12						



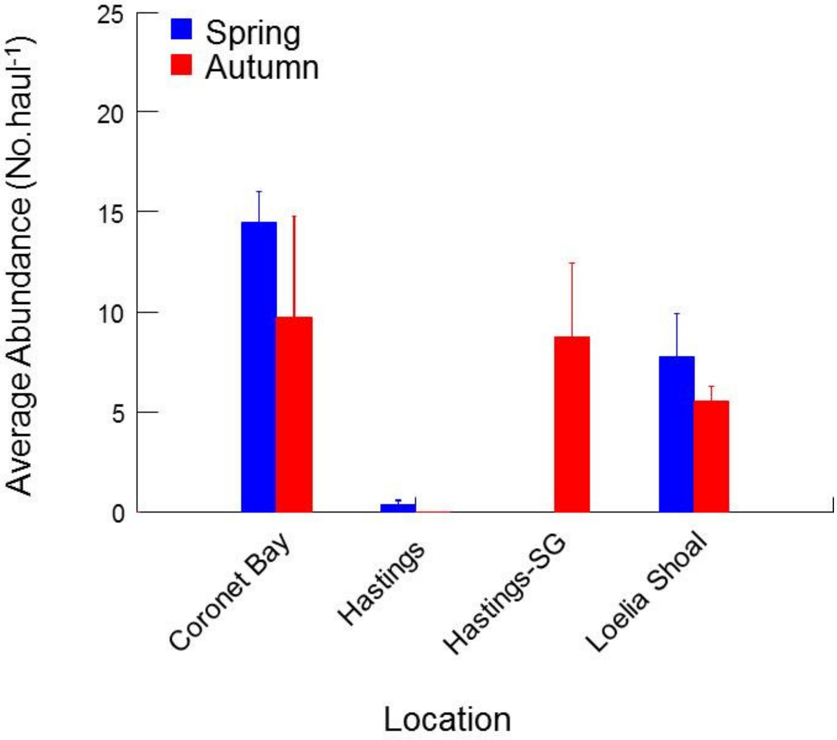
Coronet Bay: *Caulerpa*
Hastings: Invertebrate Isolates
Hastings-SG: *Zostera* seagrass
Loelia Shoal: *Caulerpa*

Figure 21. Average (±1 SE) abundance of leatherjackets, *Acanthaluteres* sp., collected by mini otter trawl. NB Hastings-SG location was only sampled in autumn



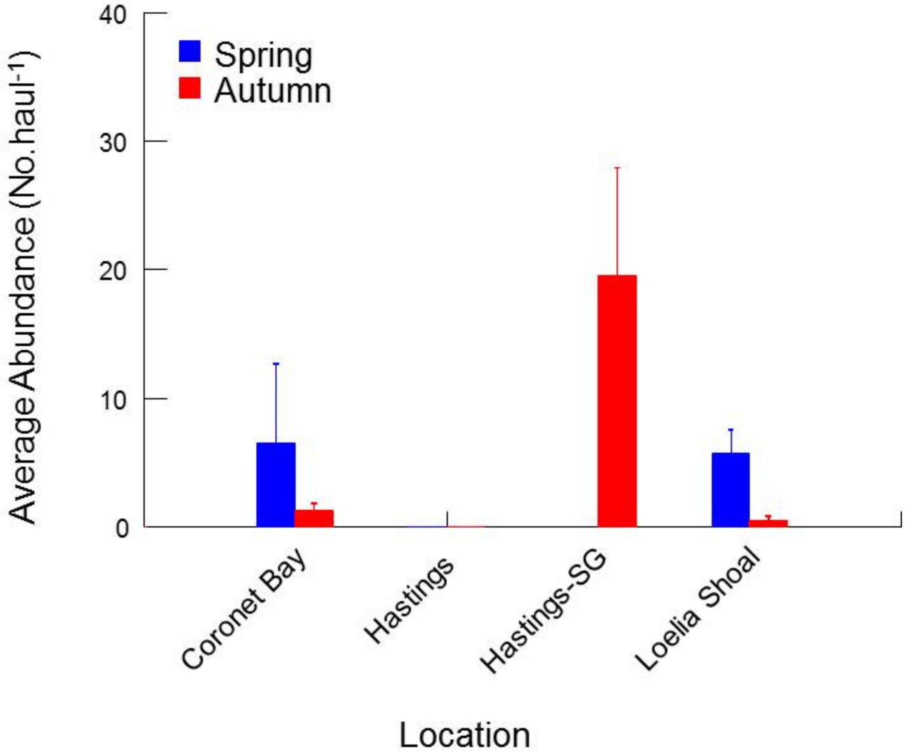
Coronet Bay: *Caulerpa*
Hastings: Invertebrate Isolates
Hastings-SG: *Zostera* seagrass
Loelia Shoal: *Caulerpa*

Figure 22. Average (±1 SE) abundance of Cobbler, *Gymnapistes marmoratus*, collected by mini otter trawl. NB Hastings-SG location was only sampled in autumn



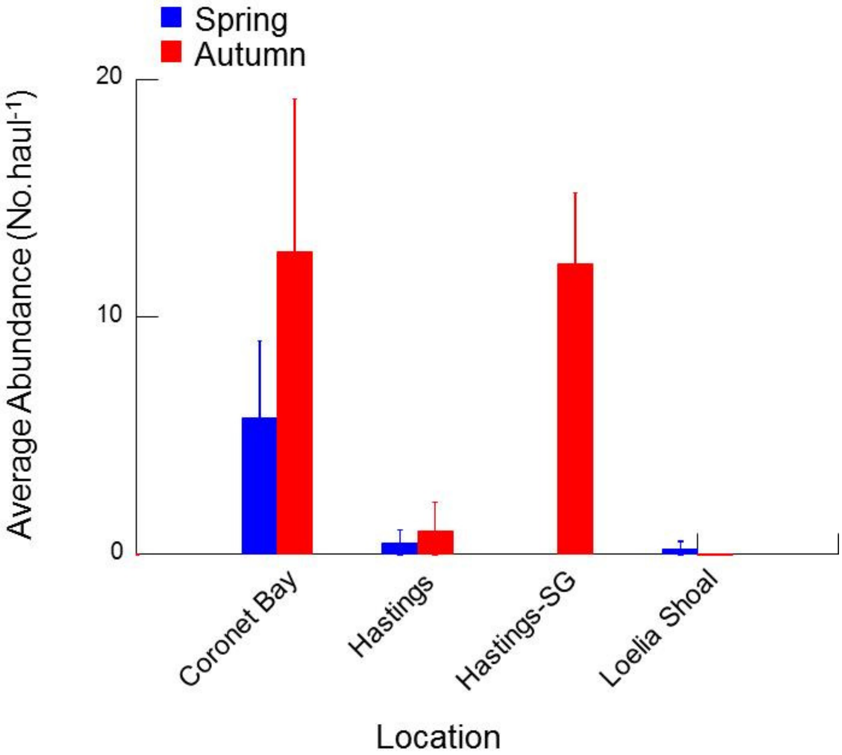
Coronet Bay: *Caulerpa*
Hastings: Invertebrate Isolates
Hastings-SG: *Zostera* seagrass
Loelia Shoal: *Caulerpa*

Figure 23. Average (±1 SE) abundance of Little Weed Whiting, *Neoodax balteatus*, collected by mini otter trawl. NB Hastings-SG location was only sampled in autumn



Coronet Bay: *Caulerpa*
Hastings: Invertebrate Isolates
Hastings-SG: *Zostera* seagrass
Loelia Shoal: *Caulerpa*

Figure 24. Average (±1 SE) abundance of Spotted Pipefish, *Stigmatopora argus*, collected by mini otter trawl. NB Hastings-SG location was only sampled in autumn



Coronet Bay: *Caulerpa*
Hastings: Invertebrate Isolates
Hastings-SG: *Zostera* seagrass
Loelia Shoal: *Caulerpa*

Figure 25. Average (±1 SE) abundance of Grass Whiting, *Haletta semifasciata*, collected by mini otter trawl. NB Hastings-SG location was only sampled in autumn

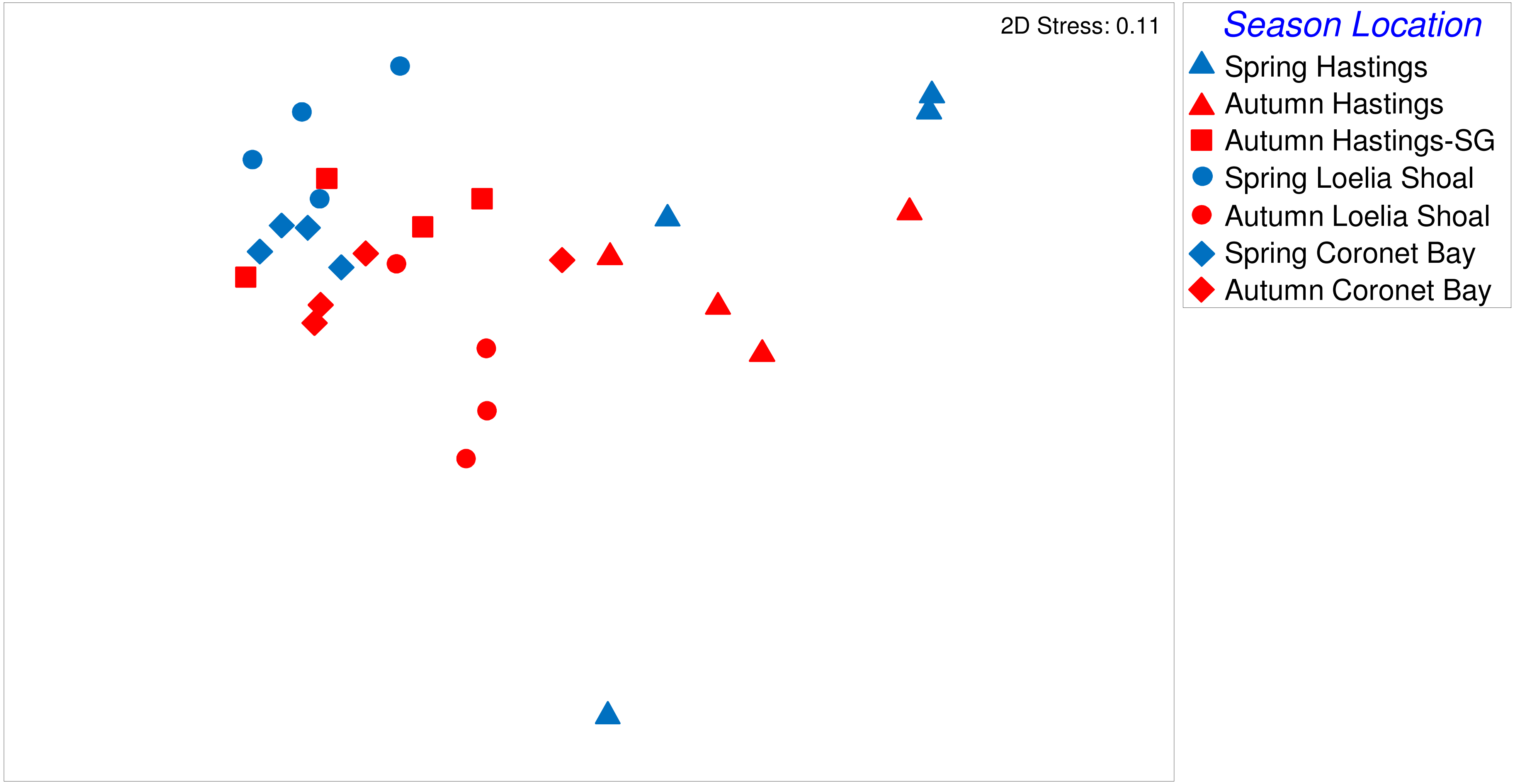


Figure 26. nMDS plot of log(x+1) transformed abundance of fish collected by mini otter trawl

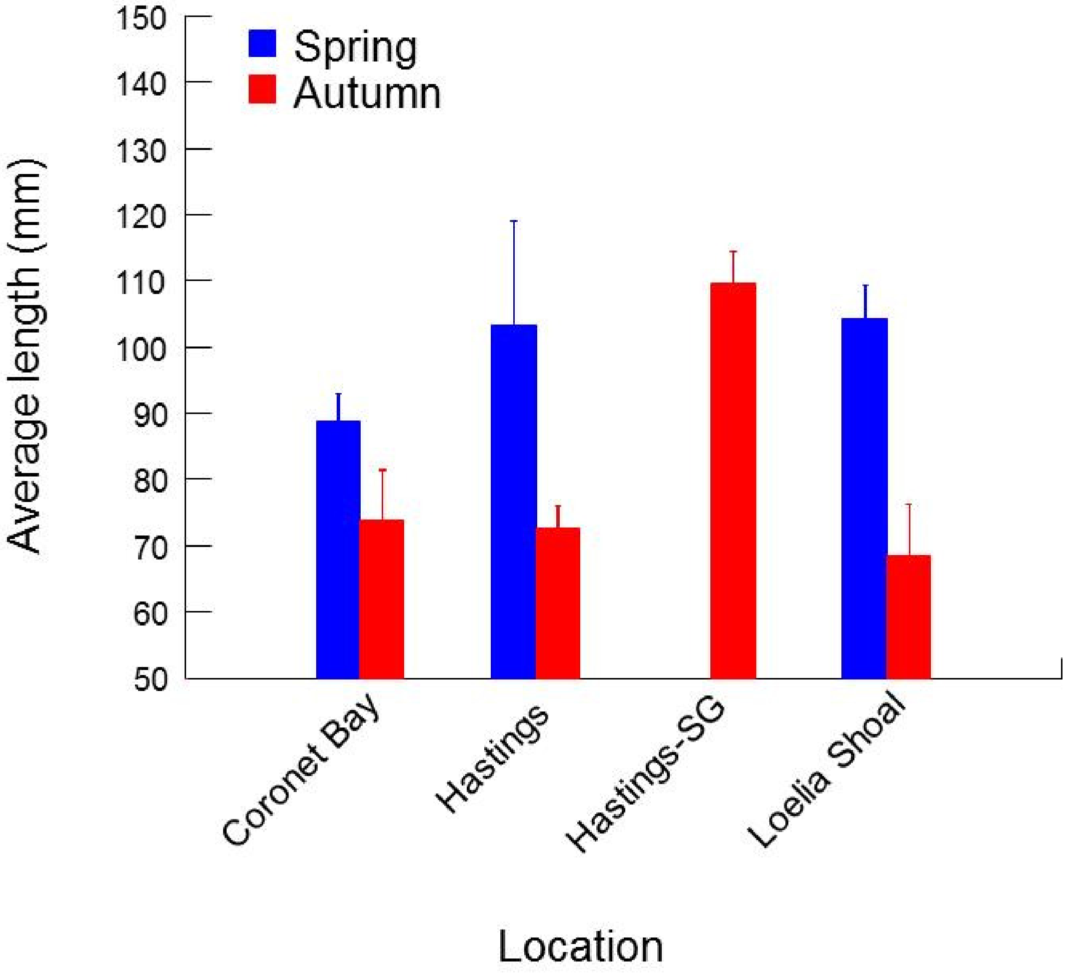


Figure 27. Average (±1 SE) length of fish collected by mini otter trawl

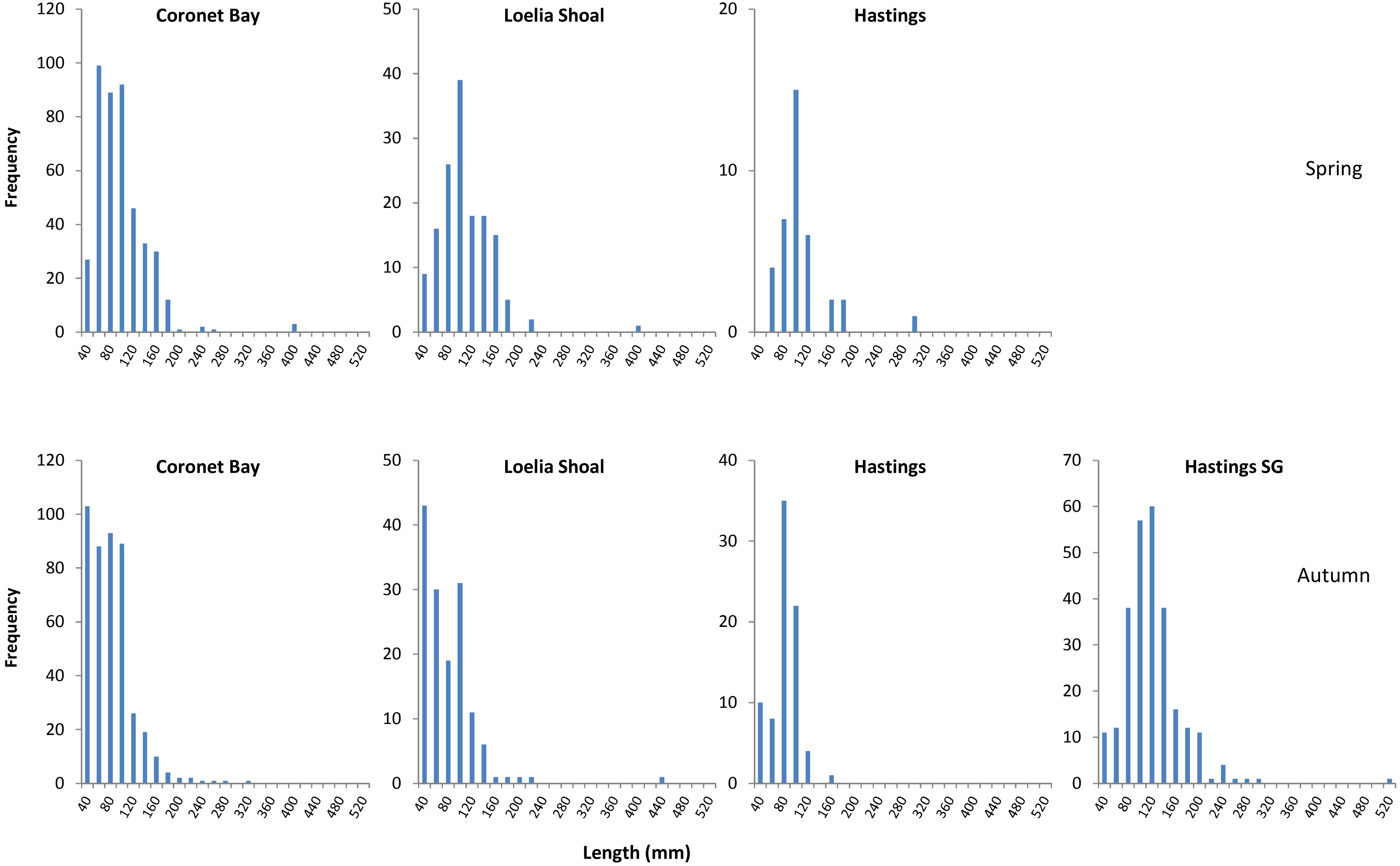


Figure 28. Length-frequency distributions for total fish collected by mini otter trawl

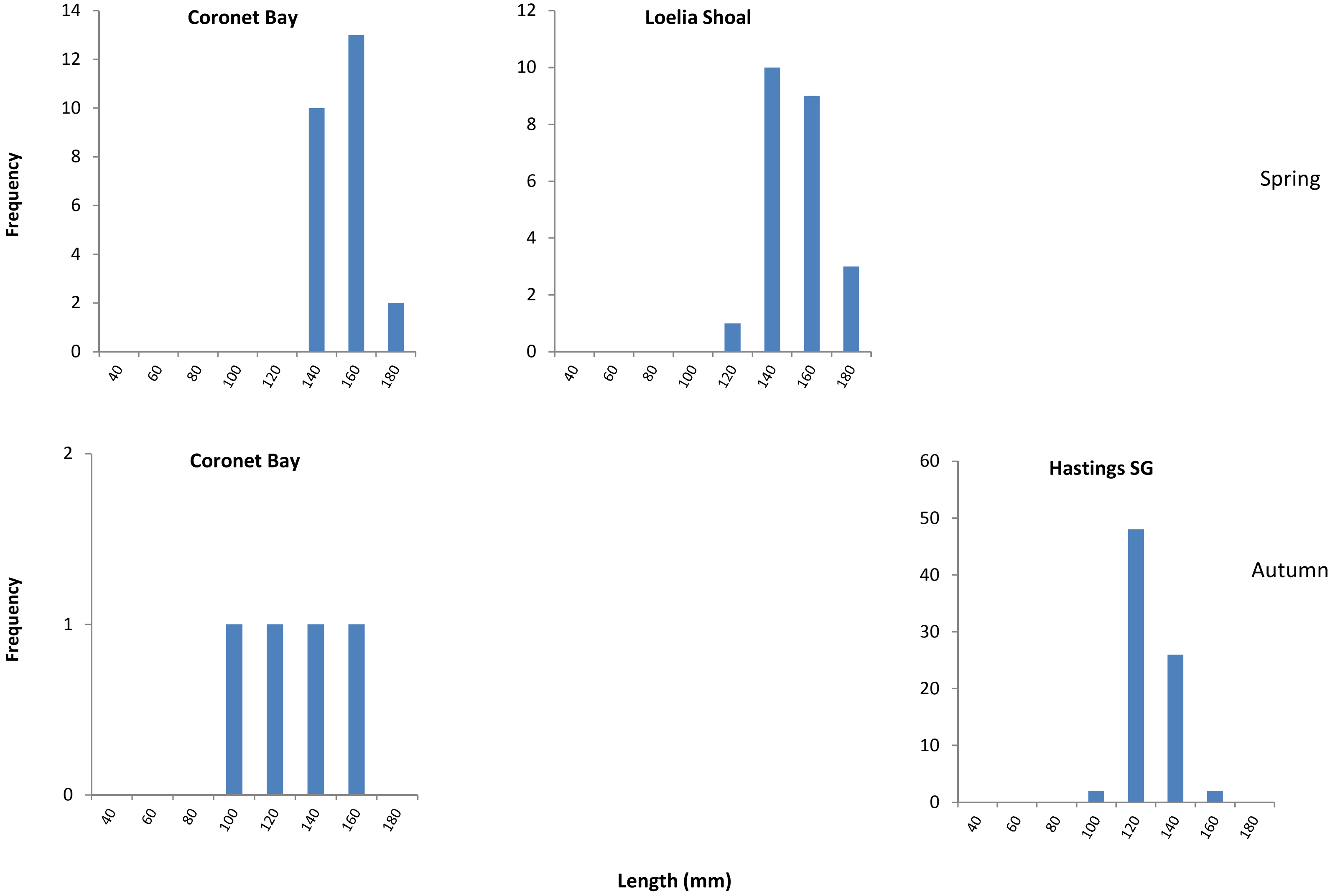


Figure 29. Length-frequency distributions for *Stigmatopora argus* collected by mini otter trawl

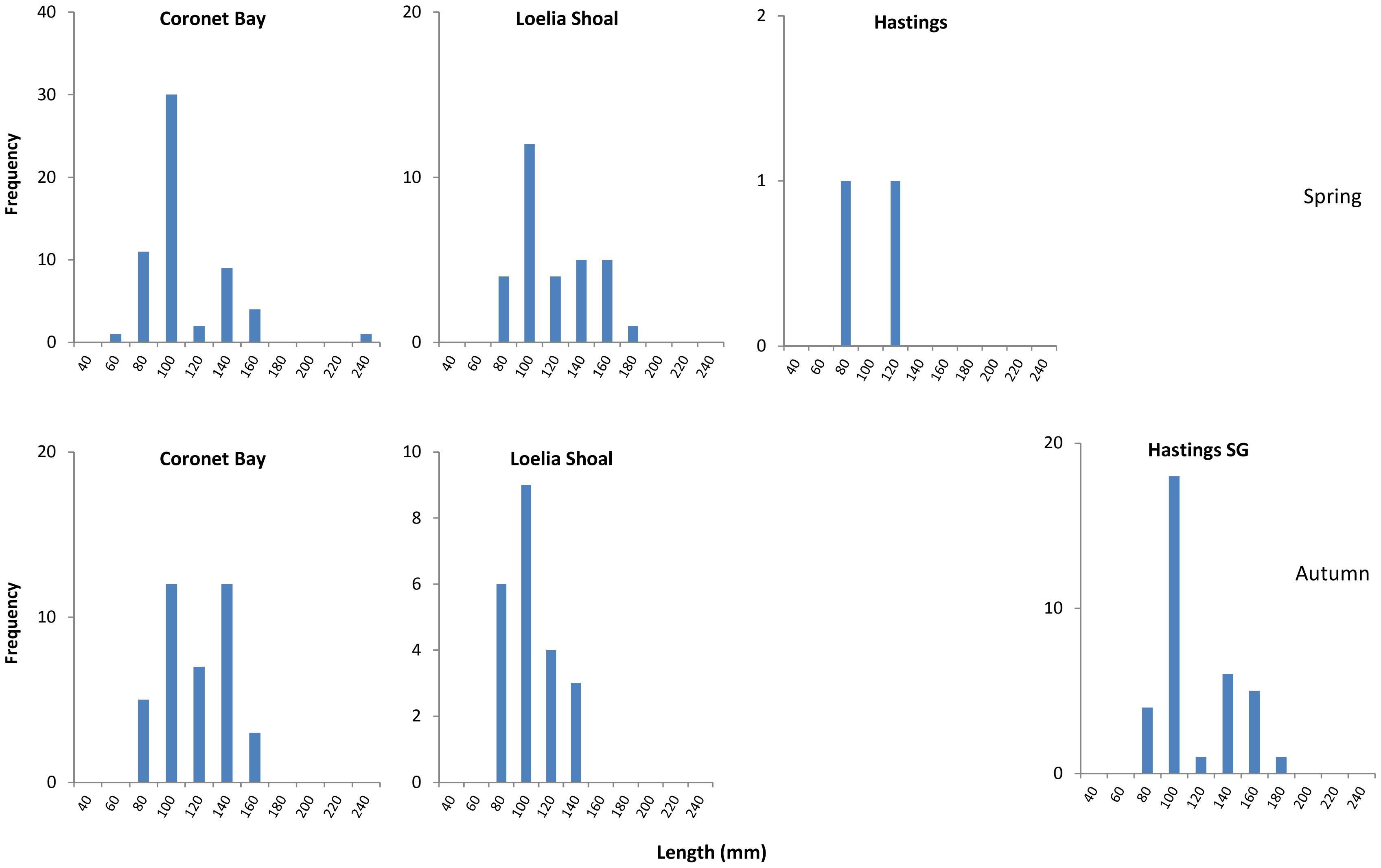


Figure 30. Length-frequency distributions for *Neoodax balteatus* collected by mini otter trawl

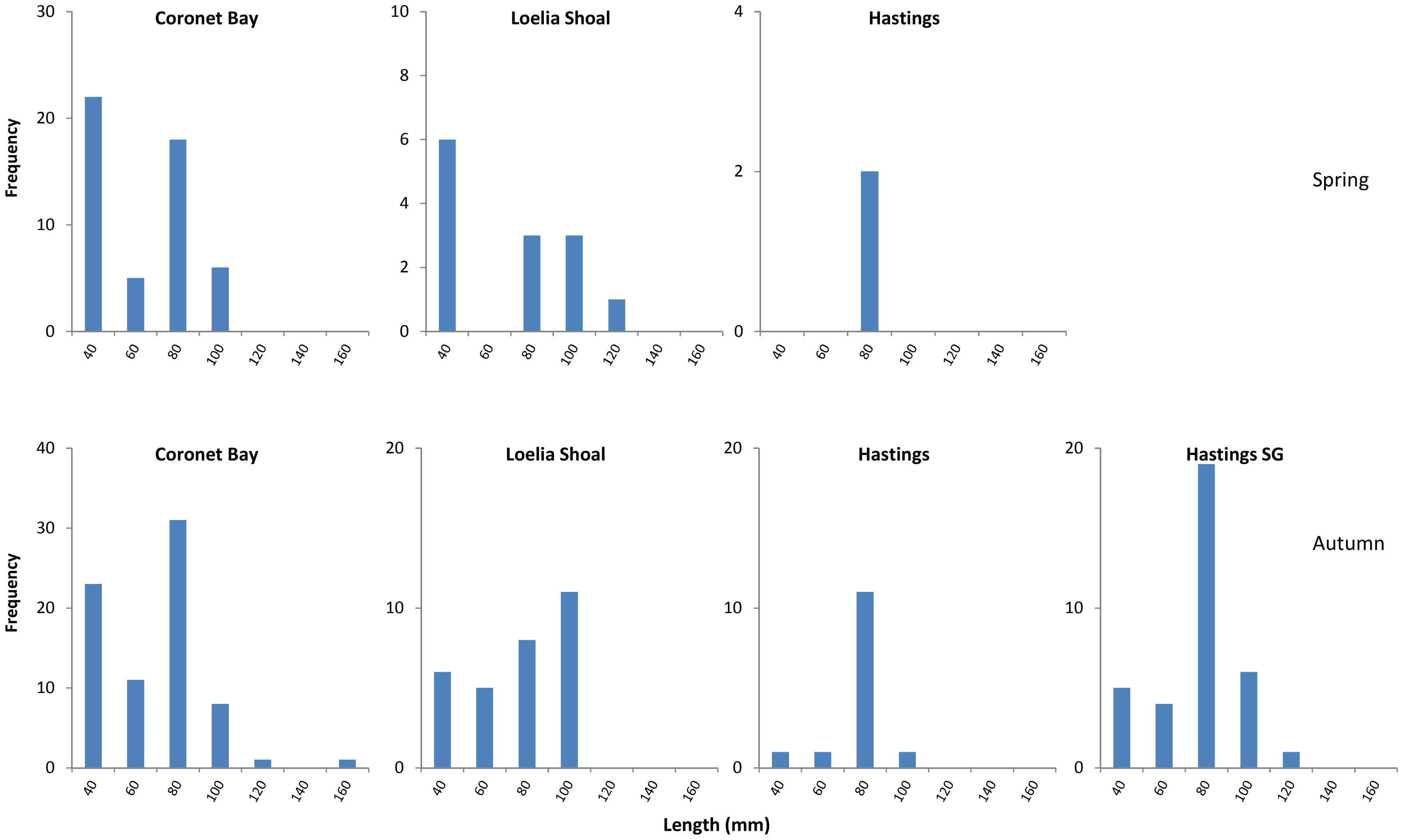


Figure 31. Length-frequency distributions for *Acanthaluteres sp.* collected by mini otter trawl

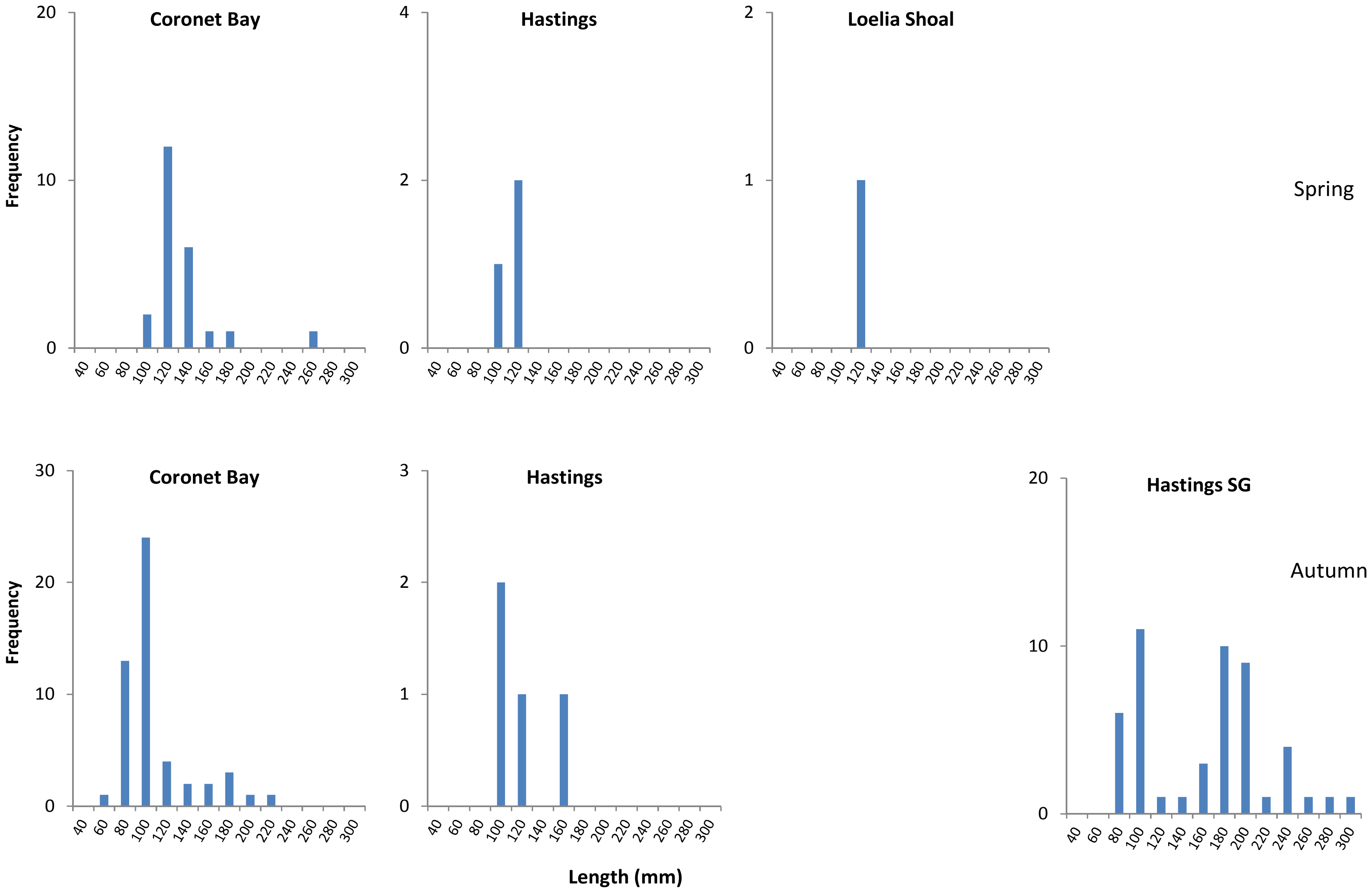


Figure 32. Length-frequency distributions for *Haletta semifasciata* collected by mini otter trawl

Discussion

Specificity of fish habitat relationships in Western Port

This study indicated that there was a spectrum of habitat requirements from relatively broad to quite specific amongst the fish species recorded in Western Port. Some species that have previously been found to be common in sub-tidal *Zostera*, such as Sixspine Leatherjacket, *Meuschenia freycineti*, Little Weed Whiting, *Neoodax australis*, Grass Whiting, *Haletta semifasciata*, and Bridled and Toothbrush Leatherjackets, *Acanthaluteres* sp., Rough Leatherjacket, *Scobinichthys granulatus*, and Southern Pigmy Leatherjacket, *Brachaluteres jacksonianus*, were also found to be common in *Caulerpa* and *Amphibolis* habitat in this study. Given that these species have previously been shown to be not associated with unvegetated habitats, the results suggest that there is an association with plant structure, rather than with a specific plant type such as seagrass. This result is supported by a number of studies that suggest that it is the presence of structure *per se*, rather than the presence of a particular habitat type, that is important to many fish species (Jenkins and Wheatley 1998, Heck et al. 2003).

Another suite of species previously found to be common in *Zostera*, including Spotted Pipefish, *Stigmatopora argus*, Cobbler, *Gymnapistes marmoratus*, Southern Cardinal Fish, *Vincentia conspersa*, and Wood's siphonfish, *Siphamia cephalotes*, were found to be common in *Caulerpa* habitat but were not recorded in *Amphibolis* habitat. This may be partly due to the inherent differences in the sampling techniques used in the two habitats, with small and/or cryptic species unlikely to be seen on underwater video. Spotted Pipefish tend to be highly camouflaged in seagrass through shape and colour, while Cobbler and Southern Cardinalfish are likely to stay within the seagrass canopy during daylight. Spotted pipefish, have, however been recorded on stereo video in shallow *Zostera* beds in Port Phillip Bay (Rajapakse 2012), indicating that the lack of this species in *Amphibolis* may not be a sampling artefact.

In general, the number of shared species recorded in the stereo video survey and the mini otter trawl sampling was relatively low. This difference would partly reflect the biases of the two methods, for example, pelagic schooling fish such as Silver Trevally, *Pseudocaranx georgianus*, and Australian Herring and Salmon, *Arripis* sp., are more likely to be recorded on stereo video than to be captured by otter trawl. Differences are also likely, however, to be a reflection of the relatively exposed, coastal environment in the Western Entrance segment compared with the more sheltered environment sampled with the otter trawl. A number of taxa recorded on stereo video would generally be regarded as coastal species. In particular, a suite of coastal reef species were mainly recorded at the Cat Bay and Point Leo locations where low- to high-relief reef was present. These species included Bluethroat Wrasse, *Notolabrus tetricus,* Herring Cale, *Olisthops cyanomelas*, Scalyfin, *Parma Victoriae*, Marblefish, *Aplodactylus arctidens,* and Rainbow Cale, *Heteroscarus acroptilis.* The more sedimentary locations with *Amphibolis* (Flinders and Balnarring) had much higher abundances of species such as *Acanthaluteres* sp., *M. freycineti*, and Odacids (*N. balteatus* and *H. semifasciata*) that were also commonly recorded in *Caulerpa* habitat. It is interesting to note that community differences in the Western Entrance segment were more related to the presence or absence of reef rather than the type of plant habitat given that macroalgae dominated at Cat Bay while *Amphibolis* dominated at Point Leo.

One species that was characteristic of the sedimentary *Amplibolis* locations (Flinders and Balnarring) as opposed to the higher-relief reef locations (Cat Bay and Point Leo) was the weedy seadragon, *Phyllopteryx taeniolatus.* In contrast to other common species from Flinders and Balnarring, *P. taeniolatus* was not recorded in the mini otter trawl sampling of *Caulerpa* and *Zostera* habitat. This is consistent with a lack of records of this species in previous sampling of *Zostera* in Western Port or Port Phillip Bay. The results suggest that *P. taeniolatus* may have a fairly specific habitat preference for *Amphibolis* beds growing on low-relief bottom, at least in the western segment of Western Port. It should be noted that in other areas, populations of *P. taeniolatus* have been recorded over seagrass, *Amphibolis* and *Posidonia*, habitat (Kendrick and Hyndes 2005) and coastal kelp, *Ecklonia radiata*, dominated reef habitat (Sanchez-Camara and Booth 2004, Sanchez-Camara et al. 2006).

Stereo video sampling in the Western Entrance segment showed both higher species richness and TiV of fish at the Flinders location compared to the other locations. This result may partly reflect the influence of water clarity on the efficiency of stereo video sampling (Shortis et al. 2009). For example, amongst locations in the Western Entrance segment, Flinders generally had the highest visibility while Balnarring had the lowest, reflecting their relative proximity to coastal waters. The effect of water clarity on sampling efficiency cannot be separated from the possibility that species richness and TiV are higher in clear waters because fish species prefer these environmental conditions (or survive better under these conditions).

Another difference between the low-relief *Amphibolis* habitats of Flinders and Balnarring compared to the higher-relief habitats of Point Leo and Cat Bay was that the former had more smaller (<120 mm), mostly juvenile, fish. This suggests that these habitats are fulfilling a “nursery” area role for some fish species, similar to *Zostera* habitat (Heck et al. 2003). Distinct seasonal differences in fish length were also apparent in stereo video sampling in the Western Entrance segment with a smaller average size of fish in autumn. Many seagrass-associated species spawn in spring, and therefore smaller juvenile individuals tend to occur in autumn compared to spring (Jenkins et al. 1997b).

Strong spatial differences in the comparison of the three “*Caulerpa*” locations mainly related to significantly reduced species richness and fish abundance at the Hastings location relative to the two Rhyll segment locations. This most likely reflects the very patchy distribution of *Caulerpa* at Hastings where it was mainly associated with small invertebrate isolates that were sparsely distributed in a habitat that was predominantly unvegetated sediment. This is in contrast to the two locations in the Rhyll segment where extensive beds of *Caulerpa* occurred, with plants growing directly in the sediment. These results suggest that similar to findings for seagrass; fish species richness and abundance is greater in vegetated, high complexity habitats than unvegetated, low complexity habitats (Ferrell and Bell 1991, Jenkins et al. 1997b, Heck et al. 2003).

The suite of species recorded in *Caulerpa cactoides* was similar to those previously recorded in sub-tidal *Zostera* in Western Port (Edgar and Shaw 1995, Hindell et al. 2004) and other Victorian bays (Jenkins et al. 1997b). This was supported by the comparison of fish recorded in *Caulerpa* habitat with those collected from *Zostera* habitat at the Hastings location. Species richness and abundance of fish in *Zostera* was in the range recorded in *Caulerpa* in the Rhyll basin, and community analysis indicated a high overlap in fish assemblage structure amongst these locations. Some possible differences were apparent, however, with an approximately five-fold greater abundance of Spotted Pipefish, *Stigmatopora argus*, at the Hastings seagrass location relative to the *Caulerpa* locations. In terms of potential camouflage, the morphology of Spotted Pipefish is much closer to *Zostera* blades than *Caulerpa* fronds. Previous studies have compared fish communities in seagrass with the invasive alga, *Caulerpa taxifolia*. York et al. (2006) conducted a field comparison of fish assemblages in seagrasses, *Zostera capricorni* and *Posidonia australis*, as well as *Caulerpa taxifolia* and found that although abundance was similar across habitats, species richness was lower in *Caulerpa*. One of the reasons for lower species richness in *Caulerpa* was fewer syngnathid (pipefish) species compared with seagrass habitats (York et al. 2006). In mesocosm experiments, Burfeind et al. (2009) compared habitat preference of three fish species for seagrass, *Caulerpa taxifolia*, and unvegetated sediment, and found that fish preferred vegetated habitats to unvegetated sediments, and between vegetated habitats preferred seagrass over *Caulerpa*. Syngnathids (pipefish) were observed attaching to seagrass but not to *Caulerpa*, possibly explaining the preference of the species for seagrass (Burfeind et al. 2009).

As was the case with locations in the Western Entrance segment, mean fish length was greater in spring than autumn for mini-otter trawl sampling. This was partly a reflection of growth of juveniles spawned in the previous spring (for example *Haletta semifasciata* at the Coronet Bay location), and also the fact that *Stigmatopora argus* were much more common in *Caulerpa* in spring than autumn. In autumn, the mean length of fish was greater in the Hastings seagrass location than the other locations. This was a reflection of the high abundance of *S. argus* in the seagrass habitat, and also the fact that two cohorts of juvenile *H. semifasciata* occurred in the seagrass location, while in *Caulerpa* only the youngest cohort was present. It is possible that larger *H. semifasciata* have a preference for *Zostera* over *Caulerpa*, although conclusions are limited by the fact that only one seagrass site was sampled, and differences may reflect spatial variation.

Resilience of fish populations to habitat loss through the use of alternative habitats

This study suggests that habitats such as *Caulerpa*, and to a lesser extent, *Amphibolis*, can provide a refuge habitat for many species commonly found in *Zostera* in Western Port. However, these habitats, both in Western Port and elsewhere (York et al. 2006), tend to occur deeper than much of the *Zostera* habitat, particularly the intertidal *Zostera muelleri*. Previous research has shown that there are often distinct differences in fish assemblages in seagrass depending on depth (Bell et al. 1992, Jenkins et al. 1997b, Jenkins et al. 2012a, Smith et al. 2012), including for *Zostera* habitat in Western Port (Robertson 1980, Edgar and Shaw 1995, Jenkins 2011). Thus, fish species that are primarily associated with shallow seagrass beds will be less likely to find refuge in these alternative habitats.

Even for fish associated with deeper sub-tidal habitats, the presence of these habitats will be unlikely to prevent major population declines of fish when *Zostera* is lost. For example, after the major decline in *Zostera* seagrass in Western Port in the 1970s, species that are associated with *Zostera*, *Caulerpa* and *Amphibolis*, such as Sixspine Leatherjacket and Grass Whiting (Jenkins et al. 1993, Edgar and Shaw 1995), showed major declines in commercial catch and catch per unit effort, indicating that although alternative habitats may provide a refuge for a small part of the population, this was not sufficient to prevent declines occurring.

Decline in fish populations after *Zostera* loss when refuge habitats are available may simply reflect the greater area of *Zostera* in Western Port compared to the other habitats. For example, habitat mapping in 1999 indicated that *Zostera* covered an area of approximately 100 km^2 compared with 20 km^2 for *Amphibolis* and < 10 km^2 for *Caulerpa* algae (Blake and Ball 2001). Before *Zostera* loss in the 1970's, the relative area of *Zostera* would have been much higher (Blake and Ball 2001). Another potential factor, however, is that the alternative habitats may be less suitable for settlement of larvae of these fish species, even though older juveniles are capable of utilising these habitats. For some species, pre-settlement larvae are distributed near the surface of the water column, and therefore larvae tend to only settle in shallow habitat. As juveniles grow they gradually move into deeper habitats. An example of this is King George Whiting, *Sillaginodes punctatus*, where pre-settlement larvae occur within the top metre of the water column (Hindell et al. 2003), and then only settle in shallow seagrass (Jenkins et al. 2012a). As the juveniles get older they move to deeper seagrass habitats (Jenkins et al. 2012b). Therefore, loss of shallow seagrass habitat, as occurred in the 1970s, will not be compensated for by the presence of deeper sub-tidal habitats. In addition to the influence of larval settlement depth, the use of alternative habitats by settling larvae will be affected by the spatial distribution of habitats. Again, using the example of King George Whiting, important areas for larval settlement are strongly influenced by current patterns delivering larvae (Jenkins et al. 1997a, Jenkins et al. 1998). In Western Port, *Zostera* beds in the area of Crib Point are known to consistently receive high settlement of King George Whiting (Robertson 1977, Jenkins et al. 2000), most likely because of their position in relation to the transport of larvae into the Western entrance. If alternative habitats do not occur in areas that receive larval settlement then they will not compensate for loss of habitat in these areas.

Understanding and Refinement of Asset Areas from the Perspective of Fish Biodiversity

This study provides data on fish biodiversity for a number of the marine asset areas previously identified for Western Port (Kent and Jenkins 2012).

The results for stereo video sampling in the Western Entrance suggest that the *Amphibolis* beds, particularly those on low-relief sediments, are a key habitat for the Weedy Seadragon, an iconic syngnathid species that is State marine emblem for Victoria. The species richness recorded at the

Flinders location was higher than recorded for *Zostera* beds using the same methods near Mud Islands in Port Phillip Bay (Smith et al. 2012). Key economic species such as King George Whiting and Southern Calamari were recorded over *Amphibolis* beds at the Point Leo location. This study lends strong support to the validity of the currently defined asset area encompassing the *Amphibolis* beds extending from Flinders to Somers (Appendix 1) (Blake et al. 2012).

This study shows that the *Caulerpa cactoides* beds that extend from Corinella southward along the coastline to near the entrance of the Bass River is an area of high fish species richness and abundance, exceeding values for the sub-tidal seagrass location at Hastings, and suggesting the asset has high biodiversity value for fish. At present these beds are not defined as a marine asset and they straddle part of the South-east Basin asset and part of the Bass River delta and Reef Island assets (Appendix 1). As such, the beds are included within two adjacent marine assets, however, the results of this study would strongly argue for an additional asset to be defined that encompasses the *Caulerpa cactoides* beds in this area.

In contrast to the *Amphibolis* beds in the Western Entrance and *Caulerpa* beds in the eastern Rhyll basin, the asset area encompassing the rhodolith beds inside the Eastern Entrance to Western Port (Appendix 1) (Harvey and Bird 2008, Kent and Jenkins 2012) appears to be of very low biodiversity for fish. Few fish species were observed on this habitat using stereo underwater video in this study in spring and autumn, supporting similar results obtained by Blake et al. (2012) at the same location using the same methods in winter. At the scale of size and movement of fish, rhodolith beds form low-relief areas of relatively low complexity (Harvey and Bird 2008), and as such may not provide sufficient habitat structure to support high fish diversity.

The results in relation to fish biodiversity associated with sedentary invertebrate isolates in the deeper channels of the Southeast Basin asset area (Appendix 1) (Kent and Jenkins 2012) were inconclusive due to poor visibility in the area. The relatively high turbidity and significant current movement would explain the prevalence of sedentary invertebrates as opposed to algae or seagrass in these deeper areas. Sampling of fish in this habitat is problematic because low visibility affects video sampling while trawl nets would become snagged on the large isolates (Figure 1). One potential sampling method for fish that could be used in the future is dual frequency identification sonar (DIDSON) (Becker et al. 2011). DIDSON uses acoustic lenses to create high-quality video images that can define the outline, shape and even fins of target fish. Importantly, the technology is particularly effective in dark or turbid conditions where visibility is otherwise poor. Further sampling is needed to refine the areas of the Southeast Basin asset that are of biodiversity value to fish, including the importance of habitats in the area to spawning of elephant fish (Braccini et al. 2008).

Conclusions

Species that have previously been found to be common in *Zostera* seagrass were also found in *Caulerpa* habitat, and to a lesser extent in *Amphibolis* habitat. Most species were able to utilise different plant habitats although some were more specific, such as the Weedy Seadragon that was only recorded in *Amphibolis* habitat. Multivariate analysis indicated that community structure was very similar between *Caulerpa* and a reference sub-tidal *Zostera* location. One distinct difference, however, was much higher abundances of pipefish in *Zostera* habitat, supporting previous studies showing that syngnathids prefer seagrass over *Caulerpa* habitats. Although there was significant overlap of species amongst sub-tidal *Zostera* and the alternative plant habitats, this may not be the case for the fish associated with intertidal and shallow sub-tidal *Zostera* (which show differences from those in deeper sub-tidal *Zostera*) because these alternative habitats tend not occur at shallow depths.

The presence of many fish species in *Caulerpa* and *Amphibolis* habitat that have been previously recorded in *Zostera* habitat suggests that these habitats may provide a refuge for these species in the case of *Zostera* loss. However, evidence from commercial fish catches after the major *Zostera* decline in the mid-1970s suggests that species capable of utilising multiple habitats still showed significant population declines. This may be partly explained by the larger area of *Zostera* habitat relative to the alternative habitats. Additionally, however, the depth and location of alternative habitats may not be as suitable for larval settlement as *Zostera* habitat. Many of the juvenile fish in the alternative habitats may have initially settled in *Zostera* habitat. Thus, alternative habitats may provide some measure of resilience by providing a refuge for a low level of fish populations in the face of *Zostera* decline, however, they will not provide protection from major population declines, and also may not provide a refuge for species where larvae settle primarily in shallow habitats or in locations dominated by *Zostera*.

Some of previously defined marine assets for Western Port were assessed from the perspective of fish biodiversity based on this study. The currently defined asset associated with *Amphibolis* beds on the western coast of the Western Entrance segment was found have significant biodiversity value for fish, including the only populations of Weedy Seadragons recorded in the study. The *Caulerpa* beds on the eastern side of the Rhyll Segment were also found to have high fish species richness and abundance, indicating significant biodiversity value for fish. These beds, however, have not been defined as a marine asset, and the results of this study would support the addition of this area to marine assets of Western Port. In contrast to *Amphibolis* and *Caulerpa* beds, very few fish species were recorded on rhodolith beds, suggesting this asset area has low value from the perspective of fish biodiversity.

The main conclusion of the study was that although some species previously recorded in *Zostera* habitat can also utilise alternative habitats, *Zostera* habitat is nevertheless the most critical for fish biodiversity in Western Port because of its extensive spatial cover and unique role for larval settlement/development in shallow areas, as well as supporting some unique species, in particular, pipefish and seahorse species. Thus, although alternative habitats provide a potential refuge for older juveniles and adults of some fish species in the event of *Zostera* loss, the maintenance of fish biodiversity in Western Port relies on the persistence of significant areas of *Zostera*, particularly in the intertidal, shallow sub-tidal zone.

Acknowledgements

We wish to thank Brent Womersley for skippering on many of the field trips. Thanks to David Hatton and Julia Kent for providing additional field work assistance. Also thanks to Matt Edmunds for providing a vessel and skippering for one of the field trips. Thanks to Julia Kent for assistance with report production.

Photograph credits are to Julian Finn of Museum of Victoria with the exception of Weedy Seadragon (John Mercer) and Spotted Pipefish (Peter Macreadie).

Many thanks to Rhys Coleman of Melbourne Water for strongly supporting this research (and the preceding Western Port Science Review) and organising funding. Funding for the research was provided by Melbourne Water, and the Department of Sustainability and Environment, and Port Phillip and Westernport CMA through the Victorian Investment Framework.

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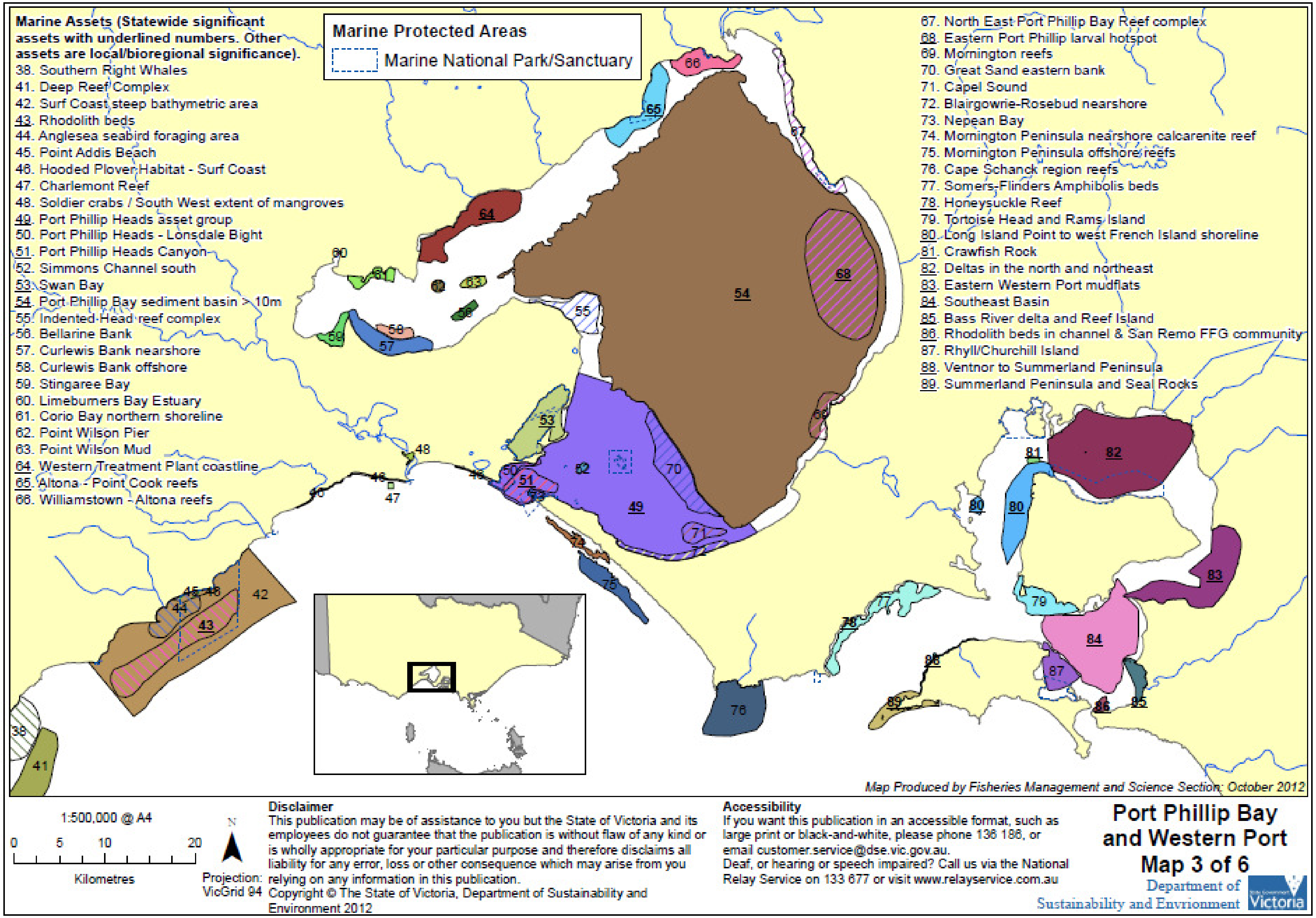
Appendix 1. Marine asset areas for Port Phillip Bay and Western Port



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