Do empty scallop shells make a suitable scallop spat collection substrate?

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ABSTRACT

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Scallops are benthic bivalves that spend the first 5 weeks of their lives swimming as pelagic larvae. Scallop larvae pass through various stages before directing themselves to the bottom and seeking a suitable substrate for attachment. In Chaleur Bay, aquaculturists have collected both sea scallop (*Placopecten magellanicus*) and Iceland scallop (*Chlamys islandica*) spat using commercial spat collectors made with mesh bags filled with Netron™. Also, in Chaleur Bay, some fish harvesters have reported seeing large numbers of scallop spat attached to discarded scallop shells. The number of scallop spat collected in traditional commercial collectors was compared to those found in experimental collectors that were constructed using empty scallop shells as substrate. The number of scallop spat in collectors with Netron™ substrate was significantly higher than the number of scallop spat in collectors with empty scallop shells as substrate or with no substrate. There was no significant difference in the number of scallop spat in the suspended plastic lantern with empty scallop shells as substrate and those with no substrate. Very low numbers of scallop spat were found in bottom collectors with empty scallop shells as substrate. Results suggest that empty scallop shells that have been cleaned are not suitable substrate for scallop spat attachment for both the sea and Iceland scallops. Fish harvesters may possibly have mistaken Jingle shell *(Anomia simplex)* spat for scallop spat. Scallop spat and Jingle shell spat look similar and require close examination to discern between them.

RÉSUMÉ

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Les pétoncles sont des bivalves benthiques qui passent les 5 premières semaines de leur vie à nager comme larves pélagiques. Les larves du pétoncle passent à travers divers étapes avant de se diriger vers le bas et à la recherche d'un substrat approprié pour la fixation. Dans la baie des Chaleurs, les aquaculteurs ont récolté à la fois le pétoncle géant (*Placopecten magellanicus*) et le pétoncle d'Islande (*Chlamys islandica*) en utilisant des collecteurs traditionnelles commerciaux fabriqués avec des sacs en maille remplis de Netron™. En outre, dans la baie de Chaleur, certains pêcheurs ont signalé avoir vu un grand nombre de naissains de pétoncles attachés à des coquilles de pétoncles retourner à la mer. Le nombre de naissains de pétoncles recueillis dans les collecteurs commerciaux a été comparé à ceux trouvés dans les collecteurs expérimentaux qui ont été construits en utilisant des coquilles de pétoncles vides comme substrat. Le nombre de naissains de pétoncles dans les collecteurs avec un substrat de Netron™ était significativement plus élevé que le nombre de naissains de pétoncles dans les collecteurs avec des coquilles de pétoncle vides comme substrat ou sans substrat. Il n'y avait aucune différence significative dans le nombre de naissains de pétoncles dans la lanterne en plastique suspendue avec des coquilles de pétoncle vides comme substrat et ceux avec aucun substrat. Un très petit nombre de naissains de pétoncles ont été trouvés dans des collecteurs sur le fond avec des coquilles de pétoncle vides comme substrat. Les résultats suggèrent que les coquilles de pétoncles vides qui ont été nettoyé ne sont pas un substrat approprié pour l'attachement des naissains de pétoncles géants ou des pétoncles d'Islande. Les pêcheurs peuvent éventuellement avoir confondu le naissain de l'anomie (*Anomia simplex*) pour le naissain de pétoncles. Le naissain du pétoncle et celui de l'anomie ont une apparence similaire et un examen attentif est requis pour le discernement.

INTRODUCTION

Both sea scallop (*Placopecten magellanicus*) and Iceland scallop (*Chlamys islandica*) spat have been collected in Chaleur Bay, Canada (Davidson *et al*. 2005 and Davidson *et al*. 2014). As adults, scallops live on the bottom; however, they spend the first 5 weeks of their lives swimming as pelagic larvae in the water column (Culliney 1974; Parsons 1994; Davidson *et al.* 2017). The scallop larvae passes through various stages (Culliney 1974) and the last stage, pediveliger, directs itself toward the bottom and attaches to a suitable substrate using a byssus filament that it secrets (Gruffydd 1978; Le Pennec 1978). Scallops are dislodged from their byssal attachment at high currents velocities (Brand 2016). In laboratory experiments, post-larval scallops were observed to re-settle easily if dislodged from where they were attached (Harvey *et al.*1993). The byssus produced by scallops does not provide the holdfast characteristic of the blue mussel byssus which permits mussels to cope with the forces of wave action and water currents (Gruffydd 1978).

By a Condition of Licence, the New Brunswick fish harvesters licenced to dredge scallops from Chaleur Bay must shuck their scallop catch at sea prior to entering port. Conversely, the scallop roe can be landed if permission is granted by the Canadian Food Inspection Agency (CFIA) via a protocol with fish buyers / processors. In Chaleur Bay, the fish harvesters usually discard the scallop shells at sea, on the bed from where they are fished.

Alternative markets for scallop shells may provide additional revenue to harvesters. Scallops shells are a source of calcium oxide (Buasri *et al.* 2013; Xing *et al*. 2013) and the shells of many scallop species are sold as cookware and for decorative purpose (http://www.ebay.com/bhp/scallop-shells). Chaleur Bay fish harvesters could request an amendment to their condition of licence if selling scallop shells was economically viable. Many fish harvesters consider discarded shells to be suitable substrate for the scallop spat attachment. This notion of shells serving as suitable substrate for recruiting scallop spat has been based on anecdotal observation provided by some fish harvesters who claim to have seen many scallop spat attached to the discarded shells.

The purpose of this study is to investigate the suitability of empty scallop shells as substrate to collect scallop spat by comparing the settlement number of scallop spat on empty scallop shells to that on Netron™, the substrate used in traditional scallop spat collectors employed by aquaculturists.

STUDY SITE

The study was conducted in the Fisheries and Oceans Canada (DFO) Gulf Region in Scallop Fishing Area (SFA) 21A at the Kenny Aquaculture Ltd's culture site which is situated off the coast of Stonehaven, New Brunswick in Chaleur Bay, Canada. (Figure 1).

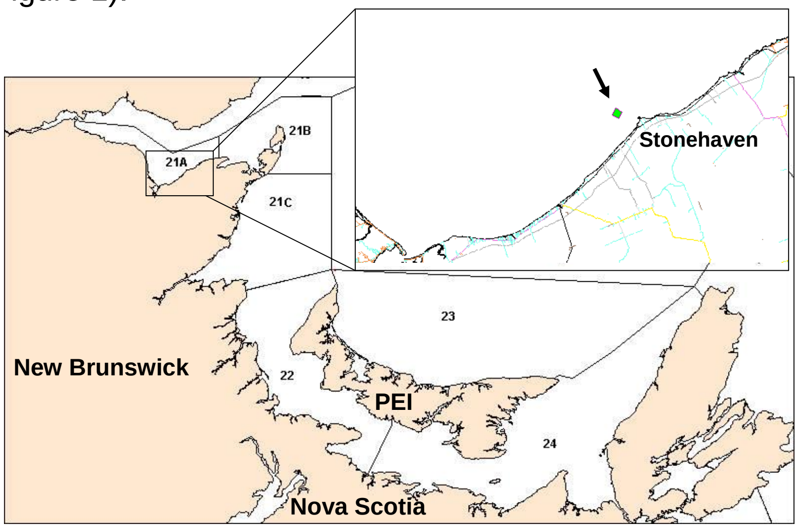

Figure 1. DFO Gulf Region with the Scallop Fishing Area (SFA) 21A, 21B, 21C, 22, 23 and 24 with an insert showing the Kenny Aquaculture Ltd's culture site off the coast of Stonehaven New Brunswick, Canada.

MATERIALS AND METHODS

Experimental collectors were prepared to compare the spat collection efficiency of empty scallop shells to Netron^{TM}, the substrate used in the aquaculturist's traditional spat collectors.

The traditional scallop spat collectors were made with 3 mm mesh bags filled with two pieces of Netron^{TM}, a polyethylene mesh measuring 40 cm × 100 cm (Figure 2).

Figure 2. Traditional scallop spat collectors made with 3 mm mesh bags filled with two pieces of Netron^{TM}.

Traditional scallop spat collectors were suspended in the water column on longlines. To facilitate the handling and deployment, the collectors were tied in pairs and 10 pairs of collectors were tied in a V shape line (Figure 3).

Figure 3. Assembly of the traditional scallop spat collectors: 20 collectors tied 2 by 2 in a V shape.

The empty scallop shells used in this study as collector substrate were obtained from commercial fish harvesters while sea-sampling in Chaleur Bay. The average shell size was 99.89±17.14 mm. After the fish harvester had shucked the scallops, their shells were scraped clean using a wire brush. Since the traditional spat collectors are suspended, it was necessary to also suspend the scallop shells to eliminate the location variable. Suspending the scallop shells in the same mesh bags used to make the traditional collectors was not physically possible. Instead plastic lanterns covered with screen mesh bag were used to construct suspended experimental collectors as follows: 1) Empty plastic lanterns (no substrate), 2) Plastic lanterns with secured scallop shells (scallop-shell substrate), 3) Plastic lanterns with Netron^{TM} (Netron^{TM} substrate) (Figure 4). The “no-substrate” collectors allowed the assessment of the plastic lantern itself as a suitable substrate for spat settlement. The scallop shells were secured using tie-wrap. The same amount of Netron^{TM} that is used in the traditional collectors was used in the Netron^{TM} substrate experimental collector. These collectors were secured on the same long line and at the same depth as the traditional collectors.

Since discarded scallop shells are normally found on the bottom, an additional set of experimental collectors that could be deployed on the bottom were fabricated using Vexar ^{TM} bags with empty scallop shells as substrates that were secured using tie-wraps. The Vexar ^{TM} bags were attached to an Aquamesh cage to raise the bags off the bottom to prevent silt accumulation (Figure 5). These collectors were also secured on the same longline as the traditional collectors.

a) b) c)

Figure 4. Suspended experimental collectors a) No substrate b) Scallop shell substrate c) Netron™ substate.

Figure 5. Bottom experimental collectors with scallop shell substrate.

Six bottom experimental collectors and six of each type of suspended experimental collectors were deployed at the culture site at the same time and on the same longline as the traditional commercial spat collectors (Figure 6). The experimental collectors and the bottom collectors were placed at three locations on the longline: at the beginning, in the middle, and at the end. The order of the experimental collector was random. The commercial traditional collectors were placed on the longline between the experimental collectors.

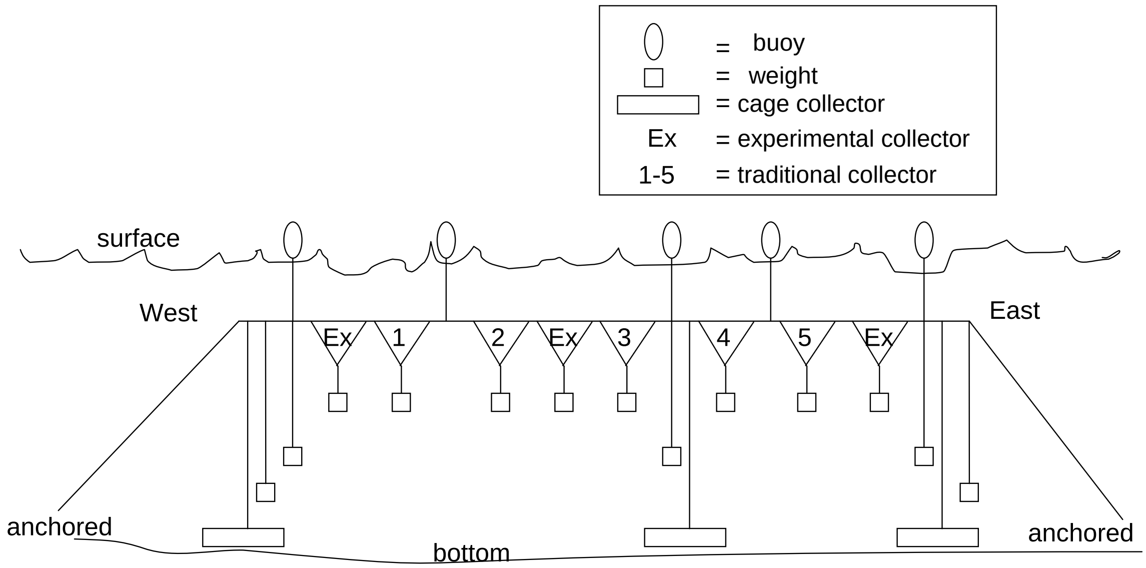

Figure 6. Schematic of the longline partially depicting the placement of the traditional commercial collectors and experimental collectors**.**

All the collectors were deployed on September 27, 2010 and left in the water for nearly one year. The experimental collectors along with 6 traditional collectors were retrieved on September 20, 2011. An additional 3 traditional collectors were retrieved on November 1, 2011. Each collector was placed in a plastic bag and frozen until it could be processed. Processing a collector consisted of placing it in a tub, opening it and removing its substrate. Water was sprayed to clean off the animals found in the collector and on its substrate. Once the collector and the substrate were cleaned, they were removed from the tub. After the cleaning, the substrates in the collectors were closely examined to detect any remaining animals. The water with the animals that came out of the collectors was poured through a 250 µm sieve to capture the content of the collectors. The contents were then transferred to a jar and fixed with 10% buffered formaldehyde for at least 3 days. The content was then transferred to a jar with 70% ethanol until they were examined to identify and count all the species within. The shell height of all the scallop spat found was measured. If the contents contained more than 200 scallops, a weighted sub-sampled was taken to facilitate the processing.

Sea scallop and Iceland scallop spat counts were compared using and an ANOVA. The counts were normally distributed and data were not transformed before analysis. The difference in settling rate was compared using Scheffé's test. Analyses were conducted using Statistical Analysis Software (SAS) version 9.3. Additional analysis concerning the other species in each type of collector was not conducted.

RESULTS

The most abundant species found in the collectors were: Iceland scallop (*Chlamys islandica*), Hiatella (*Hiatella arctica*) and sea scallop (*Placopecten magellanicus*). Many other species including jingle shells *(Anomia simplex)* were also found in the collectors (Appendix 1).

Only one experimental collector had been lost (Plastic lantern with Netron^{TM}). The traditional collectors were retrieved randomly from the middle, top and bottom of the longline. Upon close inspection of the substrate after the cleaning, it was noticed that scallop spat were no longer attached to the Netron^{TM} or the discarded shells. But, jingle shells (*Anomia simplex*) were still securely attached to the shell substrate. The jingle shell spat did resemble the scallop spat; however they could be discerned from the scallop spat, upon closer examination (Figure 7).

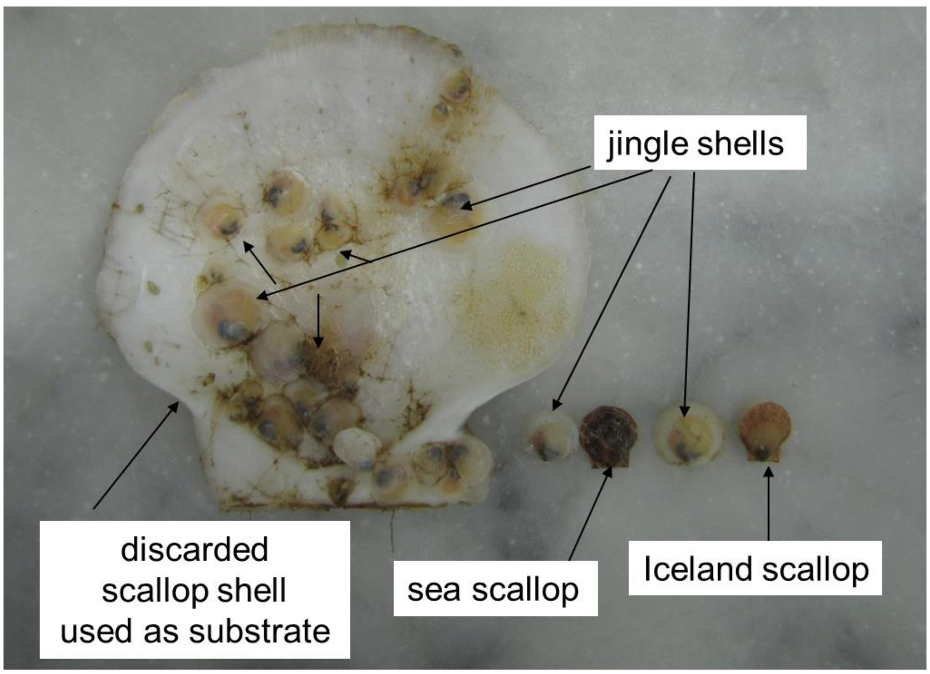

Figure 7. Jingle shells still attached to the scallop shell substrate after cleaning and the comparison of jingle shells to sea scallop and Iceland scallop spat.

The average number of sea scallop spat and Iceland scallop per collector can be found in Table 1.

Table 1. Average number of sea scallop and Iceland scallop spat/collector (±SD) retrieved September 20, 2011 and indication of no significant difference (NSD).

Collector location	Collector type	Substrate	Number of collectors retrieved	Sea scallop / collector Avg ± SD	NSD *	Iceland scallop/ collector Avg ± SD	NSD *
Bottom	Vexar™ bag on cage	Empty scallop shells	6	0.3 ± 0.8		10.7 ± 8.9	
Suspended in the water column	Plastic lantern	Empty scallop shells	6	74.8 ± 59.3		328.3 ± 333.3	
	Plastic lantern	None	6	175.8 ± 68.0		669.3 ± 441.1	
	Plastic lantern	Netron™	5	466.8 ± 43.6		3868 ± 1836.8	
	Traditional mesh bag	Netron™	9	451.3 ± 103.3		1500.2 ± 326.3	

*Line indicates no significant difference based on the Scheffé multiple comparison procedures.

The number of scallop spat for both the sea scallop and Iceland scallop differs significantly between the various spat collectors (Table 2). The Scheffe's test comparisons were significant at the 0.05 level. The traditional collectors and the suspended plastic lantern with Netron™ substrate yielded the highest settlement rate of scallop spat. For the sea scallop, there was no significant difference in the number of spat between these two collector types. For both the sea scallops and Iceland scallops there were no significant differences between the spat counts in the no substrate plastic lantern and scallop-shell substrate plastic lantern. The spat counts found in the bottom scallop-shell substrate collector were very low and differed significantly from all the others.

Table 2. Results of the ANOVA of spat count. 'Pr>F' values less than 0.05 are considered significant.

Species	Source	df	F-Value	Pr >F
sea scallops	Collector type	4	60.14	<0.0001
Iceland scallops	Collector type	4	21.65	<0.0001

DISCUSSION

The very low numbers of scallop spat found in the scallop shell substrate bottom collectors does suggest that the empty cleaned scallop shells used in this study are not suitable for scallop spat attachment. The Kenny Aquaculture Ltd's farm had been identified as a potential site for sea scallop spat collection in a previous study (Davidson *et al*. 2014). One of the criteria of an economically viable scallop spat collection site is collecting 500 or more scallop spat/collector (Cropp and Frankish 1989) when collectors are harvested. In this study, the plastic lantern with Netron^{TM} and the traditional collectors with Netron^{TM} did collect economically viable numbers of sea scallop and Icelandic scallop spat. Icelandic scallops were also collected in sufficient numbers in the empty plastic lantern and the plastic lantern with the scallop shells. The counts found in these collectors do confirm the Kenny Aquaculture farm site as a potential site for spat collection. The very low spat counts found in the bottom collectors can therefore not be due to a lack of scallop spat in the area.

The fact that there were no significant differences between the numbers of scallop spat in the no substrate plastic lantern collectors and the scallop shell substrate plastic lantern collectors confirms that the empty scallop shell substrate is not a suitable substrate for the attachment of sea or Iceland scallop spat. Moreover, the numbers of scallop spat found in the scallop shell substrate plastic lantern collectors were lower than those with no substrate for both the sea and Iceland scallops as if the shells were a slight deterrent for the spat.

According to Mann (1988) the recruitment of bivalve larvae to the benthos is influenced by several factors. One of the factors is the availability of suitable substrate and with certain bivalves exhibiting substratum specificity. Based on a scallop video survey conducted for population assessment, Stokesbury *et al*. (2016) reported sea scallops to be highly grouped in patches (beds) and strongly associated with coarse sand-granule-pebble substrates. Hart and Chute (2004) reported that juvenile sea scallops (*Placopecten magellanicus*) are mainly found on gravel, small rocks, shells, and among branching animals and plants that permit attachment of juveniles and that adult sea scallops are typically found in seabed areas with firm sand, gravel, shells and cobble substrate. Typically, the areas with an abundant sea scallop population have low levels of inorganic suspended particulates (fine clay size particles) (Hart and Chute 2004).

Dionne *et al.* (2004) conducted a literature review of the commercial scallop spat collection methods used worldwide. The research concentrated on the type of substrate for optimal spat collection and they observed that innovative changes in scallop spat collectors were directed at improving the structural characteristics like the mesh size rather than the type of material. The onion bag filled with gill net which is a still used today in some areas, does not always produce the best results in comparative studies. In general, thermoplastic mesh substrate such as

Netron™ has proven to be an excellent synthetic material to use since it is easy to handle, effective, and can last for several years. However, it is more expensive than other materials used in comparative studies. Dionne *et al.* (2004) concluded that the best performing test substrates were dead hydrozoans which captured 2.8 to 4.7 times more scallops spat than other collectors but their use on a commercial scale was not yet feasible.

In nature, scallop spat have been found to make use of a variety of substrates. The spat of queen scallops (*Chlamys opercularis)* have been observed to settle on hydroids and bryozoans in Plymouth south-west England (Pickett and Franklin 1975). Stewart and Howarth (2016) reported that branching bryozoans act as settlement habitat for scallops. Howarth *et al.* (2011) conducted a diving survey in a fully protected marine reserve and on commercially valuable scallops and benthic habitats in Lamlash Bay, Isle of Arran, United Kingdom. They found the abundance of juvenile scallops to be greater within the marine reserve than outside. A multivariate analysis revealed the greater abundance of juveniles to be related to the greater presence of macroalgae and maerl (an accumulation of red coralline algae) within the reserve boundaries. This complex habitat appeared to have positively encouraged spat settlement. In Chaleur Bay, NB, Harvey *et al.* (1993) observed Iceland scallop spat were mainly found on only a few types of substrata, particularly the perisarc of dead hydroids *Tubularia larynx.* In 1990, these authors found scallop spat to be mostly on red algae and hydroids and there were 20 times more scallop post-larvae attached to dead rather that live hydroids.

The hydroid, *Tubularia larynx,* is a common bio-fouling species on sea scallop (Robinson *et al.* 2016). Since the scallop shells used as substrate in this study had been cleaned and dried prior to being attached in the plastic lanterns or in the Vexar bags, their poor spat collection result may or may not be compared to those of discarded shells. The scallop shells that the fish harvesters discard on the scallop beds could possibly provide a habitat for hydroids onto which sea spat could attach. In our study, all scallop spat inside the collectors detached from the substrate when the collectors were cleaned. However, the Jingle shell *(Anomia simplex)* spat remained firmly attached especially to the scallop shell substrate. Since the Jingle shell spat did resemble the scallop spat and could only be discerned from the scallop spat upon close examination, it is possible that the fish harvesters may have mistaken Jingle shell spat for scallop spat when they reported seeing scallop spat on the discarded shells.

Exploring alternative markets for the scallop shells may still not be viewed as a desirable activity even though this study demonstrated that cleaned empty shells are not primary habitat for scallop spat recruitment. The discarded scallop shells do serve as a settlement substrate for some species such hydroids which have been observed as suitable substrate for the scallop spat (Pickett and Franklin 1975).

CONCLUSIONS

1) Cleaned empty scallop shells do not serve as suitable substrate for scallop spat attachment for either sea or Iceland scallops.
2) Fish harvesters may possibly have mistaken Jingle shell *(Anomia simplex)* spat for scallop spat when they reported seeing large numbers of scallop spat on discarded scallop shells.

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APPENDIX 1

	Location				
	Suspended				Bottom
	Type of collector and substrate				
Species name	Empty Plastic lantern	Plastic lantern with scallop shells	Plastic lantern with Netron™	Traditional, mesh bag with Netron™	Shells in Vexar™ bags on cage
	Number / collector ± SD				
Iceland scallop *(Chlamys islandica)*	669.3±441.1	328.3±333.3	3868.0±1836.8	1514.0±343.0	10.7±8.9
Hiatella *(Hiatella arctica)*	504.0±320.8	321.2±287.5	1828.0±1005.6	691.3±234.9	22.3±22.8
Sea scallop *(Placopecten magellanicus)*	175.8±68.0	74.8±49.3	466.8±43.6	451.3±103.3	0.3±0.8
Jingle shell *(Anomia simplex)*	107.3±57.1	184.5±144.5	140.0±71.0	44.2±35.0	20.2±13.1
Blue mussel *(Mylilus edulis)*	6.7±9.7	8.0±14.5	17.6±21.5	56.2±60.0	1.3±1.8
Sea star	17.3±16.7	23.7±13.6	42.4±24.6	6.0±6.5	5.8 ±5.5
Brittle star *(Ophiura sp.)*	0.7±1.6	2.8±3.1	2.4±3.6	4.4±6.8	12.7±4.7
Cockle *(Cardiidae)*	0.0±0.0	0.0±0.0	5.6±6.7	1.3±2.8	5.2±6.7
Toad crab *(Hyas sp.)*	0.0±0.0	0.7±1.6	0.0±0.0	0.4±1.3	6.7±5.0
Sea slugs *(Nudibranchs)*	10.0±10.0	5.0±6.7	0.0±0.0	1.3±2.8	0.2±0.4
Barnacle *(Balanus sp.)*	0.0±0.0	1.0±1.7	0.0±0.0	0.0±0.0	0.0±0.0
Worms	27.3±20.5	29.3±25.6	78.4±57.2	20.7±16.6	7.7±15.9
Shrimp	0.0±0.0	0.7±1.6	0.0±0.0	0.0±0.0	1.8±2.9
Whelk	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	5.2±9.3
Moon snail	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.2±0.4
Clam	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	17.7±38.4
Cunner	0.0±0.0	0.2±0.0	0.2±0.4	0.0±0.0	0.0±0.0
Soft shell clam	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	2.7±6.5