# THE EFFECT OF OCTOPUS PREDATION ON A SPONGE-SCALLOP ASSOCIATION

Thomas J. Ewing , Kirt L. Onthank and David L. Cowles

Walla Walla University Department of Biological Sciences

## ABSTRACT

In the Puget Sound the scallop *Chlamys hastata* is often found with its valves encrusted with sponges. Scallops have been thought to benefit from this association by protection from sea star predation, but this idea has not been well supported by empirical evidence. Scallops have a highly effective swimming escape response and are rarely found to fall prey to sea stars in the field. Consequently, a clear benefit to the scallop to preserve the relationship is lacking. We propose that octopuses could provide the predation pressure to maintain this relationship. Two conditions must first be met for this hypothesis to be supported: 1) Octopuses eat a large quantity of scallops and 2) Octopuses must be less likely to consume scallops encrusted with sponges than unencrusted scallops. We found that *Chlamys hastata* may comprise as much as one-third of the diet of giant Pacific octopus (*Enteroctopus dofleini*) and that *E. dofleini* is over twice as likely to choose an unencrusted scallop over an encrusted one. While scallops are a smaller portion of the diet of *O. rubescens* this species is five times as likely to consume scallops without sponge than those with. This provides evidence the octopuses may provide the adaptive pressure that maintains the scallop-sponge symbiosis.

## INTRODUCTION

The two most common species of scallop in the Puget Sound and Salish Sea area of Washington State are *Chlamys hastata* and *Chlamys rubida*. These scallops are often symbiotic with one of two species of symbiotic sponge, *Mycale adhaerens* and *Myxilla incrustans*. This association has generally been characterized as mutualism. The sponges that encrust on living scallops show a slower accumulation of sediment and a higher survival rate than ones that encrust on dead scallop valves (Burns and Bingham, 2002), suggesting that scallop movement helps keep the sponge unfouled by sediment. The scallop will also swim if disturbed by sponge-eating nudibranchs, also providing the sponge with defense from predators (Bloom, 1975).

The benefit to the scallop is less clear. While no study has identified a harmful effect on the scallop by sponge encrustation (Donovan *et al.*, 2002), no clear benefit has been demonstrated either. It has been assumed that the sponge deters sea stars that would otherwise prey on the scallop (Bloom, 1975). However, an extensive study of sea star predation in the Puget Sound revealed very few scallops in sea star stomach contents, and in only 6 of 3000 direct feeding observations of sea stars were scallops being consumed (Mauzey *et al.*, 1968). These observations were distributed among four of the most common species of sea star predators in the area: *Pycnopodia helianthoides*, *Pteraster tesselatus*, *Evasterias troschelii*, and *Orthasterius koehleri*. It has been found that sponge encrustation is not a deterrent to scallop predation by *Pycnopodia helianthoides* (Bloom, 1975). Further, *Pteraster tesselatus* will consume an encrusting sponge along with the scallop, so symbiosis may actually prove to be a liability in the case of this species. In addition, *C. hastata* has a rapid swimming escape response that keeps it out of reach for most sea stars, likely contributing to the low predation rates. Considering this, it seems unlikely that avoidance of sea star predation is a major benefit to the scallop. In order to consider this relationship as mutualism, some other benefit of the sponge to the scallop must be determined.

Personal observations of the giant Pacific octopus, *Enteroctopus dofleini*, have suggested them to be a major predator of *C. hastata* and *C. rubida* in the area near Deception Pass. This scallop predator has likely been overlooked because previous quantifications of *E. dofleini's* diet in Alaska and Canada have not found scallops to be a significant portion of the giant Pacific octopuses' diet in those regions (Dodge and Scheel, 1999; Hartwick *et al.*, 1981; Vincent *et al.*, 1998).

The other species of octopus that resides within *C. hastata's* range is the east Pacific red octopus, *Octopus rubescens*. *O. rubescens* also consumes *C. hastata*, but scallops do not appear to constitute as large of portion of the diet as they do for *E. dofleini* (Anderson *et al.*, 1999). *O. rubescens,* is very abundant in the Puget Sound—Salish Sea area, however, so even moderate consumption by this species could exert import selective pressures on the scallop-sponge symbiosis.

It has not been determined whether either *E. dofleini* or *O. rubescens* preferentially consume scallops which are free of sponges. Such a determination would provide a mechanism by which the symbiosis is perpetuated and provide direct evidence that this scallop-sponge relationship is mutualistic.

Two conditions must be met to show that predation by these octopuses provide the selective pressure to maintain the scallop-sponge relationship:

1. Octopuses must consume a substantial number of scallops in the wild
2. Octopuses must show a preference for scallops without encrusting sponges

Previous work has shown that in the Mediterranean Sea, *Octopus vulgaris* predation on the sympatric scallop *Arcoa noae* in the lab decreased when the scallop was coated with the sponge *Crambe crambe*. However, this study failed to demonstrate whether *O. vulgaris* predated on *A. noae* in the wild. (Marin & Lopez Belluga, 2005)

The purpose of this study was to show that *Chlamys hastata* is a substantial component of the diet of these octopuses. Additionally we will show that *Octopus rubescens* and *Enteroctopus dofleini* preferentially consume scallops without sponge encrustation over scallops with sponge encrustation in a captive situation.

## METHODS

We collected middens from six *E. dofleini* dens near Coffin Rocks, Washington State by SCUBA during July and August 2005 ranging in depth of 6 to 15m. Dens were initially located by the presence of a midden pile, and then confirmed to be an octopus den by the presence of an octopus. Once the presence of an octopus was confirmed, the entire midden was collected and brought back to the station to be sorted and identified. During sorting, old shells were discarded as they may have been unearthed from the sediment as the octopus was excavating its den (Dodge & Scheel, 1999). Shells were determined to be old if they were stained or had encrustations such as algae or bryozoanson the interior . Crab carapaces recovered from the midden samples rarely survived transport from the den to the lab, and so were recorded while collecting the midden. The number of individuals was determined for each taxa in every midden (Figure 1).

We collected *Chlamys hastata* by SCUBA from Northwest Island. “Symbiotic” scallops were encrusted with *Myxilla incrustans* while “non-symbiotic” were cleaned by wire brush to insure no presence of sponge.

We collected 6 male *Octopus rubescens* ranging from 46 to 250 g at 15 to 20m depth from Admiralty Beach on Whidbey Island, Washington. These octopuses were transported to Rosario Beach Marine Labs and housed in a 4 gallon tank with running seawater. We allowed the octopuses to acclimate to captivity for at least one week and maintained them on a diet of *Nuttallia obscurata* (Mollusca:Bivalvia) and *Hemigrapsus nudus* (Crustacea:Brachyura). After the acclimation period we ran trials on six *O. rubescens* to determine preference between symbiotic and non-symbiotic scallops. In each test we placed four symbiotic and four non-symbiotic scallops in the tank with the octopus, one of each type in each corner close enough to each other that the octopus would likely encounter both scallops simultaneously. As soon as the octopus made a choice and consumed one scallop we removed the octopus, replenished the scallops and returning the scallops to their starting positions for a subsequent trial with a different octopus. Each trial was continued for each octopus until the octopus made no choice of scallop for two hours, at which time we changed to another octopus.

We captured one *Enteroctopus dofleini* at Coffin Rocks by SCUBA. This octopus was housed in a large, 750-gallon flow-through tank with darkened walls and a large plastic trashcan into the tank to act as a den. We conducted scallop preference trials with this species at night, their normal foraging time. For each trial we placed 10 non-symbiotic and 10 symbiotic scallops in a pile in the center of octopus holding tank late in the evening. The next morning we recorded how many symbiotic and nonsymbiotic scallops were eaten. If any scallops were eaten we removed all scallops from the tanks until the next trial. If no scallops were eaten, we left the scallops in the tank until the octopus chose to feed. In order to ensure that the octopus could feed to satiation, if the octopus consumed more than half the scallops in any given trial we increased the number of scallops presented at the next trial to double what the octopus had eaten previously, while still maintaining the equal number of symbiotic and non symbiotic scallops

Picture 1. *E. dofleini* hunting near Rosario Beach Marine Lab, Washington State

Picture 2. *C. hastata* with valves encrusted with orange *M. incrustans* sponge.

Picture 3. *Octopus rubescens* examining two scallops, *Chlamys hastata*, one with sponge encrustation and one without.

## RESULTS

Our analysis of middens collected from the dens of *Enteroctopus dofleini* supports the hypothesis that the scallop, *Chlamys hastata*, comprised a substantial portion of the diet of the giant Pacific octopus (Figure 1). In the six middens examined in the field, scallops comprised about one-third the total number of individual prey. Additionally, preliminary data suggests that scallops comprise about 10% of prey items in *O. rubescens* middens

In laboratory tests with *Octopus rubescens* we ran 19 total trials and obtained 13 choices. In those trials *O.rubescens* chose non-symbiotic scallops more than five times more often than symbiotic ones, a significant difference (Figure 2).

With *E. dofleini,* after an acclimation period in which the octopus chose not to eat at all, the octopus chose non-symbiotic scallops over symbiotic one at a ratio of to two to one, a highly significant difference (Figure 3).

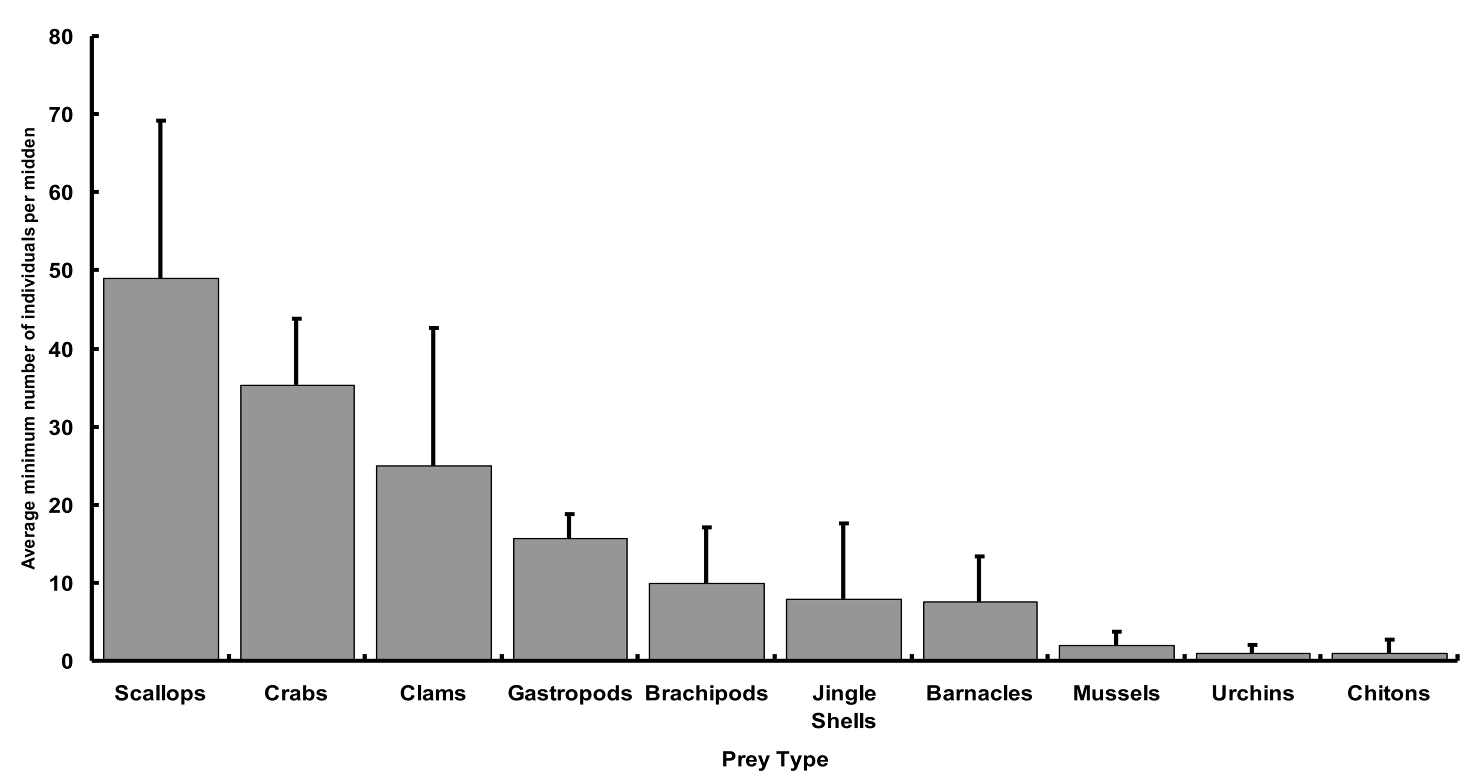


Figure 1 Average number of individuals from middens of *Enteroctopus dofleini* near Deception Pass, Washington. (n=6 middens)

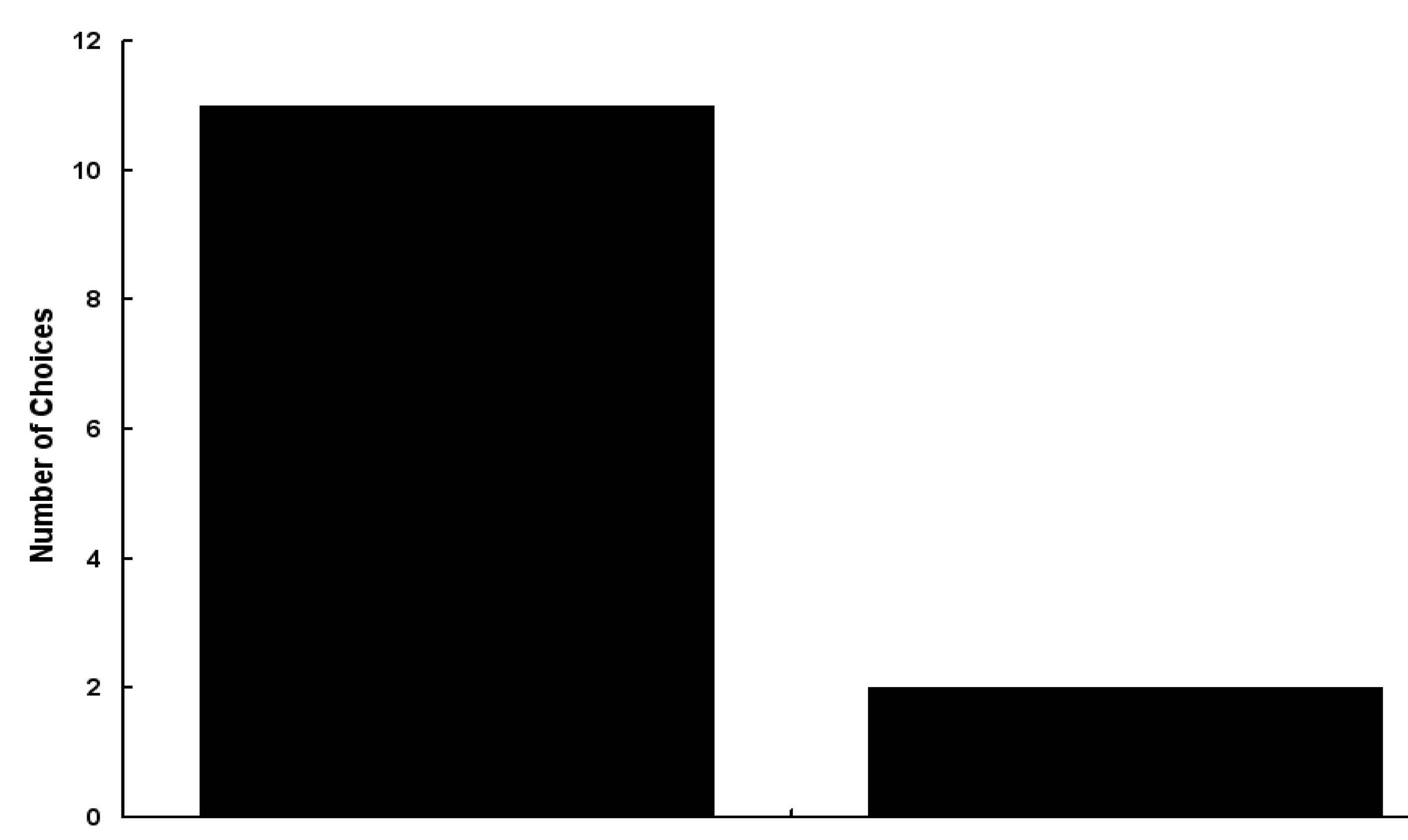


Figure 2. Number of scallops eaten by *Octopus rubescens* with symbiotic encrusting sponges on valves (Symbiotic) and without symbiotically encrusting sponges on valves (Non-symbiotic). The difference is significant (Chi-square with Yate's correction, p=0.0265)

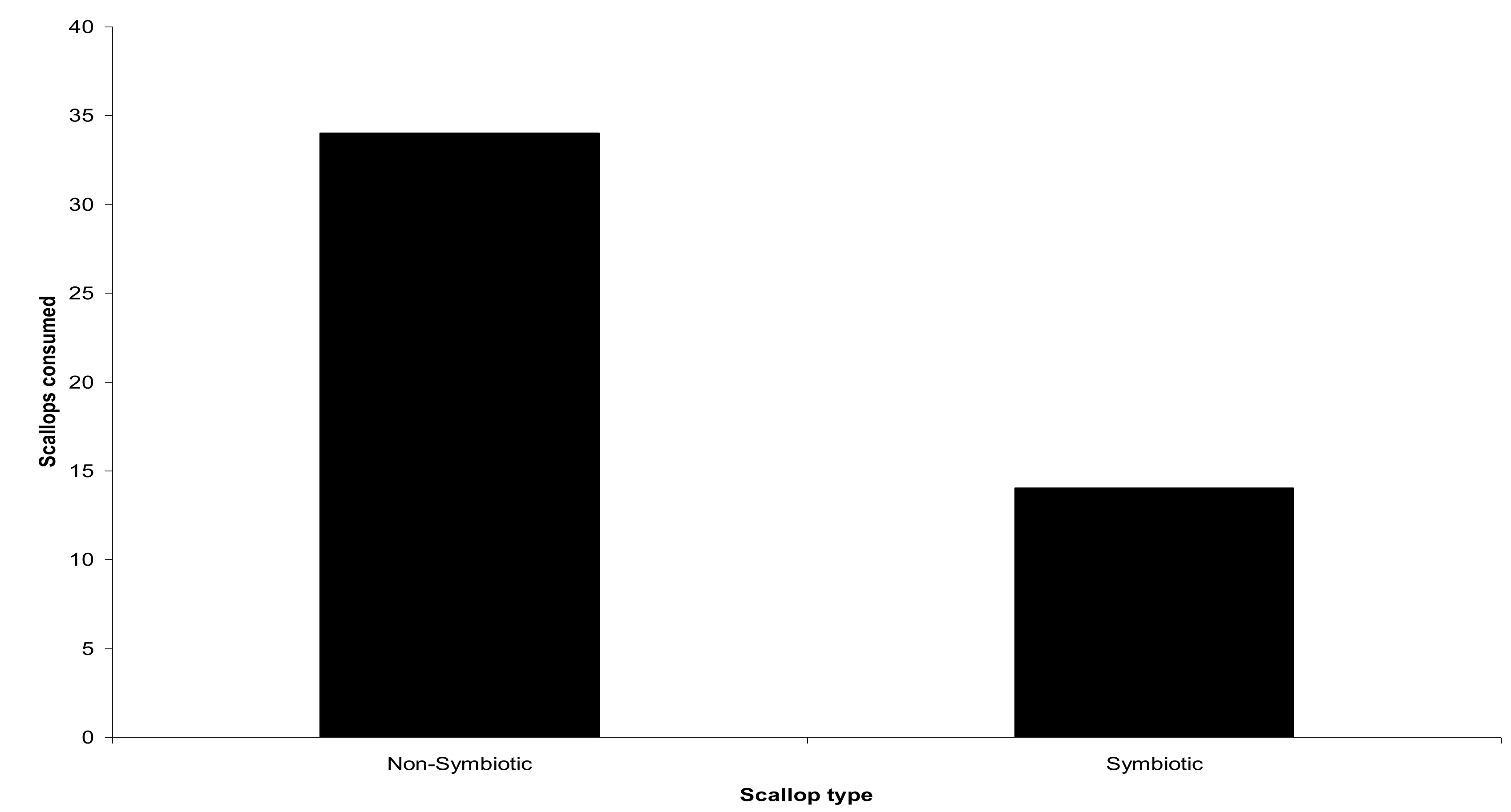


Figure 3. Number of scallops eaten by *Enteroctopus dofleini* with symbiotic encrusting sponges on valves (Symbiotic) and without symbiotically encrusting sponges on valves (Non-symbiotic). Difference is highly signficant (Chi-square with Yate’s correction, p=0.006)

## DISCUSSION

Both *Octopus rubescens* and *Enteroctopus dofleini* were shown to consume significantly more scallops without a symbiotic sponge than those with sponges in laboratory tests. This suggests that octopuses avoid sponge-encrusted scallops in the wild. Further, scallops appear to comprise a substantial portion of the diet of both octopuses. The two conditions necessary to establish octopus predation as an important selective factor for maintaining the mutualistic relationship between scallops and sponges in the Pacific Northwest thus appear to have been met. We therefore propose that octopus predation is an important selective factor, and may even be more important than sea star predation is for maintaining the sponge-scallop symbiosis.

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