# SITE FIDELITY AND HOMING BEHAVIOR OF THE INTERTIDAL STICHAEIDAE, *XIPHISTER ATROPURPUREUS* (BLACK PRICKLEBACK)


by

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Alan Shanks

To investigate site fidelity and homing behavior in the intertidal Stichaeidae, *Xiphister atropurpureus*, mark and recapture studies were conducted at South Cove, Cape Arago Park, in Oregon from July to August 2012. A total of 35 *X. atropurpureus* were captured, tagged, released, then repeatedly surveyed by conducting numerous census days over a period of 46 days. Out of this total, 15 fish were tagged and released at their home sites and 20 fish were tagged and displaced at varying distances from their home sites (10, 30, 50, or 150 m). Of the 15 fish rereleased at their home sites, a total of 5 were recaptured at or within 1.5 m of their home site. The recapture rates (13% for home site; 20% for neighboring site) for fish tagged and released at their point of capture indicate that site fidelity is highly likely in this particular species. Of the 20 fish displaced from their home site, only 1 fish from the 30m-displacment group was recaptured. Recapture rates (0% for home site; 20% for neighboring site) for homing behavior indicate that it remains a possibility but requires further studies to determine if it is exhibited in this species. A simple population size estimate was carried out using a

Lincoln-Peterson estimate with a Bailey's adjustment, providing an estimate of approximately 0.77 to 1.47 fish per 100 $m^2$. Site fidelity and homing behavior may be influenced by competitive or territorial behavior and a dispersed population could allow for resource availability.

**Key terms:** Homing, Intertidal, Site fidelity, Stichaeidae, *Xiphister atropurpureus*

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## Introduction

*The intertidal zone*

The intertidal zone is a dynamic environment subjected to variable conditions determined by the tides. The tides, which are the rising and falling of sea level due to the gravitational forces of the sun and moon upon the earth, influence the conditions of the intertidal zone and the behaviors of its inhabitants. On the Oregon (OR) coast, there are mixed semi-diurnal tides, in which higher high and lower high and higher low and lower low tides occur nearly every day. Shore topography and local wind and weather patterns may also affect tides and intertidal conditions. Bays, coves, and estuaries influence tidal heights either through magnification or dissipation while offshore winds move water away from the coastline and onshore winds draw water to the shoreline (NOAA Ocean Service Education). Such a range of factors can have an impact upon the behavior of intertidal organisms, such as seen in the intertidal movements of fishes, who must adapt to these constantly variable conditions.

Intertidal fish can be classified as either residents or visitors, depending on their intertidal movement in relation to the tides. Resident intertidal fish spend the majority or all of their time in the intertidal zone and are thus highly restricted in their movement. They tend to possess smaller, benthic forms with cryptic coloration, territorial behavior, and limitations in locomotion. Visitor intertidal fish, in contrast, regularly enter and leave the intertidal zone with the high tides, making them generally unrestricted in movement. They are usually pelagic or demersal species with efficient locomotion and schooling behavior (Horn et al., 1999). For rocky shores, like the Oregon coast, there tends be a greater percent of resident intertidal fish at low tide due to the availability of a variety of shelters. These include tidepools, macroalgae, rock crevices, and areas under rocks & boulders. Because of the greater quantity of shelter as well as the variable environmental conditions associated with this habitat, many of the intertidal fish species have developed specific behaviors and mechanisms that enable them to survive and reproduce in the intertidal zone.

*Site fidelity and homing behavior*

Site fidelity is a behavior whereby an organism repeatedly returns to a particular site or range for a given period of time. This preference for a particular area can be associated with habitat quality, such as shelter accessibility, resource availability, and/or breeding potential. This behavior relies heavily upon the organism's ability to successfully return to or home to that favorable refuge. Homing behavior is the ability of an organism to return to a place of former occupation instead of going to other places (Horn et al., 1999). For intertidal fish, this implies that they are capable of recognizing external cues (e.g. geographical features) of their home site or range and using these cues to guide their return.

Numerous experiments have been done to show that a variety of intertidal fish species are capable of homing back to their home sites after displacement, even over considerable distances (Green, 1971; Goff & Green, 1978; Craik, 1981; Yoshiyama et al., 1992; Burt de Perera & Guilford, 2008; Jorge et al., 2012). Green (1971) conducted tagging studies on the tidepool sculpin *Oligocottus maculosus* and found that the species exhibits site fidelity and homing behavior when displaced from their tidepools into other tidepools. Craik (1981) expanded upon this by investigating the effects of age and size on homing performance in *O. maculosus* through tidepool displacements. From these studies, while there does not appear to be sex difference associated with homing success, there does appear to be greater success in larger and older individuals.

This may be due to the necessity of establishing a spatial mapping of a site, which develops in smaller and younger fish during a period of extensive movement (Craik 1981). Not strictly limited to tidepool sculpins, Burt de Perera & Guilford (2008) examined the shanny, *Lipophrys pholis*, in a series of displacement tests in which its shelter was removed from its original location and found that the species is capable of homing using spatial mapping and geographical cues. The ability to home, of course, varies from species-to-species and from individual-to-individual and is heavily influenced by shore topography, wave action, turbulence, and time of year (Horn et al., 1999).

Site fidelity and homing behavior can be attributed to natural instincts and/or intertidal conditions. The intertidal zone can be a rich source of food, especially during high tide; hence, homing behavior is often associated with foraging excursions. For visiting fish that leave with the receding tide and linger offshore, homing may not be a crucial behavior, but for those who remain even after the tide has receded, it is a matter of life or death. That is, at high tide, these fish leave their shelter in search of food and must return to their home site prior to low tide or be at risk of stranding and/or exposure to predators. Homing may also be attributed to the need to breed or spawn, particularly when it is at a location other than the home site or range. This occurs in a variety of organisms using a range of external and internal cues. It arises as a reproductive strategy to place offspring where predation is low and, at least for fish, where the number of eggs overwhelm the predator's ability to inflict high mortality (Horn et al., 1999). Homing is also implemented as a means to search for a physiologically optimum environment. This involves the seasonal or tidal movement of fish species to avoid detrimental conditions and the ability to return to an area once conditions are favorable again.

*Family Stichaeidae*

The family Stichaeidae is composed of about 65 marine species found exclusively in the Northern Hemisphere, most of which inhabit the cold waters of the North Pacific. Stichaeids, also commonly known as pricklebacks, occur at various depths from the intertidal to 700 meters. The family is characterized by taeniform morphology with a small mouth, thoracic pelvic fins, and a long dorsal fin that is sometimes joined to the caudal fin (Eschmeyer et al., 1983). The name "prickleback" is actually attributed to the spinous dorsal fin that is found in most species of the family. The long anal fin also tends to be spinous and the scales are usually either minute or absent on the body. Four genera (*Anoplarchus*, *Cebidichthys*, *Ulvaria*, *Xiphister*) contain resident intertidal fish, occupying rocky interstices or under macroalgae.

*Xiphister atropurpureus*, the black prickleback, is a resident intertidal species found in shallow waters up to 8 meters from Kodiak Island to north Baja. It can be identified by two dark bars with white edges that radiate from behind the eyes, diminutive pectoral fins, and the lack of any pelvic fins (Figure 1). Coloration may vary from a blackish or dark brown to reddish brown, with these variations often possessing a white bar at the base of the caudal fin (Eschmeyer et al., 1983). Characteristic of the genus, this species inhabits the interstices of rocky habitats or among macroalgae and is known to feed on algae, worms, and amphipods (Horn et al., 1999). Observations suggest that they may also be opportunistic scavengers (Personal observation). *X. atropurpureus* is capable of surviving the constantly fluctuating conditions of the intertidal thanks to a mechanism called bimodal respiration. *X.*

*atropurpureus* lacks a swim bladder or the gill structures to survive exposure to air, therefore this bimodal gas exchange is accomplished either through the skin or with the use of the buccal cavity. Provided it is kept moist, this species can survive out of water for at least the duration between tides.

*Research objectives*

In this paper, I present results on the homing behavior of *Xiphister atropurpureus*, an intertidal Stichaeid. The objective was to determine if *X. atropurpureus* exhibits site fidelity and/or homing behavior in the intertidal environment, particularly in the rocky marine habitat characteristic of the Oregon coast. The rationale for this objective is that resident intertidal fish tend to establish a home site or range to which, even if displaced, they are capable of returning. As *X. atropurpureus* is a resident intertidal inhabitant, I hypothesized that the species possesses the ability to consecutively return to and reside at a home site or range. The study was conducted at South Cove, Cape Arago State Park, Oregon, using the same site and basic methodology as Yoshiyama et al. (1992) utilized with tidepool sculpins.

## Materials & Methods

*Preparation*

South Cove at Cape Arago State Park, Oregon was selected as the experimental site primarily on the basis of its accessibility; that is, its relative distance from the Oregon Institute of Marine Biology (OIMB) in Charleston, OR and its ease of entry into the intertidal zone. Cape Arago State Park is located approximately eight kilometers southwest of Charleston, OR with South Cove accessible through a well-defined path. Within the south-facing cove itself, the experimental site was located primarily on the west shore in an area approximately 180 m (North-South) by 20 m (East-West), where the majority of the tide pools are located (Figure 2). Although almost all of the site fidelity and displacement tests were conducted on the west shore, a few of the fish were displaced to the east shore of the cove.

Prior to conducting the *in situ* experiment, a sedative was prepared by mixing and diluting MS-222 (tricaine methanesulfonate) with seawater to approximately 100 ppm. This was done by measuring out a dry weight of 100 mg of MS-222 and mixing it with 1L of filtered seawater under a laboratory hood. The MS-222 solution was stored in a sealable plastic container for ease of transport and spill prevention. This dosage was selected as the lowest degree of sedation necessary to carry out the method of tagging used in this experiment without harming the fish, and to allow for the rapid recovery from sedation in the field.

*Capture and tagging*

On the west shore of South Cove, *X. atropurpureus* were caught within the lower to middle intertidal zone during low tides. The fish were found under approximately one-meter diameter rocks and captured with the assistance of hand nets. It should be noted that fish were not found under any smaller rocks and that there were some rocks too large to lift or move. The ideal habitat appeared to be areas of submerged or partially submerged gravel or rock substrate and crevices no wider than a couple inches. Captured individuals were placed in the MS-222 solution for approximately 60 seconds or until a noticeable decrease in activity was observed. Once sedated, a 3 mL syringe with a 22G1/2 needle filled with non-toxic, permanent Palmer brand craft acrylic paint was used for tagging. The needle was inserted just under the skin on the right side (from a dorsal point-of-view) of the body post-anally, adjacent to the anal fin. The color of paint used for tagging varied between the displacement groups. Thus, fish displaced 150, 50, 30, 10, and 0 meters were tagged with red, white, green, blue, and yellow paint, respectively (Table 1). The syringes and needles were replaced between each displacement group. The location of the tag was chosen for the purpose of visibility, as *X. atropurpureus* are much darker dorsally versus ventrally. While under sedation, individuals were measured for total length (mm). The "home site," or the original site of capture, was marked with non-toxic, red spray paint for easy relocation. GPS coordinates were also taken and recorded for each home site. After tagging and measurement, the fish were placed in a bucket of fresh seawater for recovery from the anesthesia prior to their designated displacements. All displacements, with the exception of the 150 m displacements, were directed exactly south of the home site. The 150 m displacements were directed precisely east of the home site since the length of the west shore could not accommodate such a distance south. Because they were displaced to the east, their release site was on the East shore with a sandy-bottomed cove separating it from the West shore. Directions of the displacements were determined with a field compass and distance determined by a 100 m-tape.

Capture, tagging, and censuses occurred from July 3rd to August 16th, 2012. For the site fidelity test, 15 fish were tagged with yellow paint injections and released at their respective home/capture sites on July 7th, 2012 (Table 1). For the homing behavior test, a total of 20 fish were tagged and displaced, with 5 fish assigned to each displacement distance. Tagging and release of the 10, 30, and 50 m displacement groups occurred from July 18th-22nd, 2012 (Table 1). The 10 m-displacement group was tagged with blue paint injections and released south of their home sites on July 18th-19th, 2012. The 30 m-displacement group was tagged with green paint injections and released south of their home sites on July 21st-22nd, 2012. The 50 m-displacement group was tagged with white paint injections and released south of their home sites on July 19th-21st, 2012. The 150 m-displacement group was tagged with red paint injections and released east of their home sites on July 3rd-4th, 2012. A total of 35 *X. atropurpureus* were captured, tagged, and released. Home/release sites were dispersed throughout the mid- to low-intertidal zones, as they were determined by wherever a *X. atropurpureus* could be located and captured on that particular date.

*Census days*

During census days, we returned to the marked home sites with the aid of the GPS coordinates, and checked both the initial capture sites and the neighboring sites within 1.5 meters of the captures sites. Captured *X. atropurpureus* were checked for the tags and, if any were identified as a recapture, it was noted what test group they belonged to and whether they were caught at the home site or a neighboring site. Date of recapture was also recorded to obtain the maximum amount of days it would take to remain at or home back to their home site. After identification, *X. atropurpureus* were re-measured for their total lengths prior to being safely returned to their refuge. Length measurements were used to obtain some degree of individual identification by comparing these to their initial capture measurements.

The number of census days each displacement test received varied due to the availability of sufficient low tides to allow for access to the some of the low intertidal experimental sites. The 0 m (site fidelity test) and 150 m displacements were given longer test durations as well as a greater quantity of census days (Table 2). This was to ensure that the 150 m-displacement group had plenty of time to home back to their home sites if such a behavior were to occur. As for the site fidelity test, a longer duration and frequent censuses increased the chances of recapturing a tagged individual at its home site or one of the many neighboring sites. Thus, the 0 m displacement test was given a duration of 40 days with eight census days while the 150 m displacement test lasted 44 days with ten census days. The 10, 30, and 50 m displacement tests had durations of 29, 26, and 28 days, respectively. The number of census days for these displacements ranged from 5-6 days (Table 2).

*Data Analysis*

With the acquired data, a Lincoln-Peterson estimate with a Bailey's adjustment was conducted to estimate the approximate size of the *X. atropurpureus* population residing on the West shore of South Cove (Bernard & Hansen, 1992). It assumes that: 1) the population should be geographically and demographically closed, 2) each member of the population has the same probability of capture, 3) an individual that has been captured once does not change its probability of being captured again, 4) tagged individuals randomly mix with untagged individuals between census days, and 5) tags are permanent and recognizable. The following equation was used to determine the approximate population size ($N_B$):

$$N_B = [(N_2+1)\ N_1]/(M_2+1)$$

Where $N_2$ is the number of animals captured in subsequent samples, $N_1$ is the number of animals captured and tagged in the initial sample, and $M_2$ is the random variable recording the number of animals in the subsequent samples that are tagged.

## Results

*X. atropurpureus* home sites were rocks with relatively flat undersides with either gravel or macroalgae underneath. Home site characteristics (i.e. shelter area, immersion level, quantity of neighboring sites) varied from location to location, though the diameter of the rocks under which the fish took shelter generally did not exceed one meter. This was because not all rocks within the experimental location could be lifted by one or two individuals. Over a period of 46 days, a total of 35 *X. atropurpureus* were tagged, released, and repeatedly surveyed. Out of this total, 15 fish were tagged and released at their home sites to assess site fidelity and 20 fish were tagged and displaced at varying distances from their home sites to assess homing behavior.

### *Home site releases*

Eight census days were conducted for the site fidelity test, spanning 40 days. Of the 15 fish released at their home sites, 5 were recaptured at either their home sites or at neighboring sites within 1.5 meters of the home sites (Table 2). Two of the five *X. atropurpureus* were recaptured at their home sites with a time interval of 11 days between release and recapture. The other three *X. atropurpureus* were recaptured at neighboring sites 1 day and 28 days after release (Table 3). Thus, there was a 13% recapture rate for fish captured at their home sites and a 20% recapture rate for fish captured at their home site and nearby neighboring sites. The mean length of fish used in the site fidelity test was 134.7 mm, with a minimum length of 100 mm and a maximum length of 190 mm.

### *Displacement releases*

The number of census dates varied for each displacement group due to the availability of lower low tides (Table 2). The 10 m-displacement test had 6 census days over the course of 29 days. There were no recaptures for this displacement group. The 30 m-displacement test had 5 census days over the course of 26 days; One fish was recaptured at a neighboring site 15 days after initial displacement, thus providing a 20% recapture rate for fish captured at neighboring sites for this particular displacement distance (Table 2, 3). The 50 m-displacement test had 5 census days over the course of 28 days. There were no recaptures. The 150 m-displacement test had 10 census days over the course of 44 days. There were no recaptures. The mean lengths of fish for the 10, 30, 50, and 150 m displacement groups were 101, 119, 130, and 180 mm, respectively.

*Population estimate*

Because untagged *X. atropurpureus* were not recorded on census days, an approximate range of untagged fish must be used in determining population size. Thus, the total number of untagged animals caught on subsequent samples was estimated to be between 5 and 15 fish. Given that a total of 15 *X. atropurpureus* were tagged and released at their home sites in the initial sample and 5 of these were recaptured on subsequent samples, the approximate population size on the west shore of South Cove can be calculated using a Lincoln-Peterson estimate with a Bailey's adjustment:

$$N_B = [(N_2+1)\ N_1]/(M_2+1)$$

$$N_B = [(10+1)\ 15]/(5+1) \qquad N_B = [(20+1)\ 15]/(5+1)$$

$$N_B = 27.50 \qquad N_B = 52.50$$

According to this model, the approximate total population size ($N_B$) of *X. atropurpureus* on the west shore of South Cove ranged from 28 to 53 fish. Given a sample area of approximately 180 m by 20 m, the density of the species in this habitat is estimated to be between 0.77 and 1.47 fish per 100 $m^2$.

**Discussion**

The study contributes new data on the behavior of the stichaeid, *X. atropurpureus* and serves as a comparison for other well-studied species of intertidal fish. The results indicate that *X. atropurpureus* displays site fidelity, at least over the time frame of this study. Though an understanding of the extent of homing behavior may require further studies, it is also a possible behavioral feature as site fidelity and homing are often exhibited together. On the other hand, fish that exhibit site fidelity can just as easily lack the capability to home to an area if displaced (Yoshiyama et al., 1992). Discerning whether an organism like *X. atropurpureus* exhibits site fidelity and homing is important in that it enables an improved understanding of intertidal fish movement and even allows us to perform population estimates with greater accuracy. Population estimates provide valuable information on the condition of the overall species, particularly trends in growth (i.e. reproduction, immigration) and reduction (i.e. death, emigration).

With respect to site fidelity, the recapture rates for both home sites (13%) and neighboring sites (20%) were relatively high, as compared to other studies testing site fidelity in intertidal fish. These rates may be attributed to the low number of fish tagged and released for this test. Neighboring sites were included in the study to account for the possibility of a home range rather than simply a home site. That is, the fish may not consistently remain at a single geographical site but rather wander within a small area or “range” that encompasses several possible shelters. Within this home range, several large rocks or macroalgae may be available to the fish and the size of this range may fluctuate with locality and environmental conditions (Yoshiyama et al., 1992). Fish may have larger home ranges if several large rocks are available in the area for shelter or if they must forage further distances to attain food during the high tide. In terms of the latter, readily available food may not be close at hand, requiring the fish to essentially enlarge their search area to increase their chances of obtaining food. At the same time, the fish must have shelter close at hand for when the tide recedes, making it advantageous for the fish to develop a home range where shelter and food are available and where there is lower risk of being stranded in an unfamiliar environment during low tide.

The recapture rates corresponding to homing behavior for both home sites (0%) and neighboring sites (20% for 30m-displacement) were low overall. These may be attributed to the low number of fish tagged and released for each displacement distance, which was two-thirds less than the number released for site fidelity (five fish as opposed to fifteen).

Compared to the return rates from the Yoshiyama et al. (1992) tidepool sculpin study, the site fidelity rates from my study were relatively in the same range. Yoshiyama et al. (1992) had recapture rates for home sites at 32, 41, and 25% and for neighboring sites at 38, 43, and 43% for *Oligocottus snyderi*, *Oligocottus maculosus*, and *Clinocottus globiceps*, respectively. As for my recapture rates for homing behavior, they were very low when compared to the findings from the Yoshiyama et al.(1992) study. For *O. snyderi*, there were recapture rates of 46% at the home site and 2% at a neighboring site. Comparatively, tidepool sculpins are more restricted in their intertidal movements, taking refuge in tidepools during the low tide. They are unable to leave these tidepools until the high tide. *X. atropurpureus* are capable of moving from one site to another, even during the low tide, due to their unrestricted access to rocky interstices or macroalgae and the benefit of bimodal respiration.

*X. atropurpureus* may use olfactory (i.e. chemicals) and visual cues (i.e. geographical) to return consistently to its home site (Goff and Green, 1978). Goff and Green (1978) conducted orientation and homing experiments on *Ulvaria subbifurcata*, a stichaeid, and found that olfactory cues may be involved in the steering mechanism in homing. They also indicated that visual cues might play a role in the recognition of a limited area around the home site. The likelihood of a fish returning to its home site or neighboring site by random movement alone is low due to the quantity of alternative or equally suitable habitat available to the displaced fish (Yoshiyama et al., 1992). That is, once a fish has been displaced, the fish can simply adopt the new location as its new home site. A fish that exhibits homing, however, would attempt to return to its original location regardless of the available shelter at the displacement location.

A fish's inability to home back successfully to its home site or range may be attributed to several factors. Among these is the exposure to greater predation risk due to being displaced in an unfamiliar environment. A fish may easily become prey to a predator in the process of homing back to its home site, especially if there is little refuge between the displacement sight site and the initial site of capture. Another factor includes geographical obstacles, such as sand flats or rocky prominences, which deter or even make it impossible for fish to return to their home sites. This may have been the case for the 150m-displacement group, which was displaced east rather than south. Between the displacement site on the east shore and the home site on the west shore, lies a sandy bottom expanse that makes up the substrata of South Cove. For a fish to cross this wide expanse would mean exposing itself to predators as it would lack any sort of refuge. While the seemingly harmful effects from the tagging process may be a possible factor too, it is unlikely (unless there is misapplication of the tag). Yoshiyama et al. (1992) reported keeping tagged tidepool sculpins in the laboratory for 3-4 weeks with low casualties and even recapturing fish in the field from a previous tagging year using a similar tagging procedure.

Concerning the population size of *X. atropurpureus* on the west shore of South Cove, the range (28 to 53 fish) was rather low with a density of approximately 0.77 to 1.47 fish per $100m^2$. This low density estimate may be attributed to the relatively small sample size captured and released at their home sites for the site fidelity test. It may also be a factor of shelter availability with respect to the species' preference for certain rocks for refuge, making certain shelters usable and others not. That is, the species appears to prefer rocks or macroalgae of larger area, which provide greater coverage and are less likely to be moved by predators (Personal observation). It is unlikely that the fish would take refuge under smaller rocks or algae that expose parts of their body to predators. The overall population may cluster around areas of the intertidal where the rocks would fit their preferences (i.e. larger rocks or denser macroalgae). Of course, shelter preference may be highly subjective and vary among individuals. As it is difficult to assess whether a fish is using a particular rock or macroalgae from its surface, it is likely many possible shelters were passed over, leaving the fish under them unaccounted for. Lastly, the fish included in this study were a minimum total length of 100 mm and any fish below this were excluded from the study. Numerous fish under a total length of 100 mm were observed throughout the study (approx. 25-30% total *X.*

*atropurpureus* encountered). Thus, the population estimate accounts only for fish exceeding 100 mm in total length and does not truly reflect the population size for all *X. atropurpureus* at the experimental site.

One of the primary difficulties encountered during the study was the inability to access all the neighboring sites (or rocks able to be lifted) within 1.5 meters of the home sites. That is, some possible refuges for *X. atropurpureus* were inaccessible due to the size of the rocks and the inability to lift them, even with aid. This indicates that it highly probable that some tagged or untagged fish were taking refuge under these rocks and could not be included in the data set, even though they were considered neighboring sites. Another difficulty that was encountered was the loss of some fish due to the inability to capture them upon the lifting of their rock refuges. As the fish immediately go into flight mode upon disturbance, a net and a quick hand are the only reliable way of in capturing the fish. Otherwise, the fish is more than likely to escape under a neighboring rock or into a nearby tidepool, where chances of capture are greatly diminished.

Amongst the improvements that could be made to this study, tagging and recapture should be done in the early spring as larger, mature *X. atropurpureus* are more abundant due to the start of the spawning season. The majority of captured fish in this study did not exceed 200 mm in total length while fish as long as 305 mm have been observed during the spring along with their egg masses. Rather, the fish tagged and captured during this study were likely either of the 2011 or 2012 clutch year or were immature individuals. It is likely that the larger fish either migrated to a new location, moved lower into the intertidal zone, or were simply not sighted during the study.

In the case of the former possibility, this would mean the size of the population within the intertidal zone fluctuates throughout the year in accordance with the spawning season.  Larger, mature fish (non-spawning individuals) would prove better candidates for this study as it has been shown in other intertidal fish species that there is a positive correlation between size and homing success (Craik, 1981).  Starting tagging and recapture in the early spring would also allow for a longer study duration with a greater quantity of census days.  While 46 days was a decent allotment of time to conduct the test, additional time would have provided better data as well as an opportunity to include more fish in the study.

All in all, site fidelity is a highly likely behavioral adaptation of the stichaeid, *X. atropurpureus* whereby it is capable of remaining within a geographical site or range. Homing behavior remains a possibility but requires further studies to determine if it is exhibited in this particular species.  Though a fish may exhibit site fidelity, it does necessarily mean that it also displays homing behavior.  Rather, once displaced, there would have to be some behavioral flexibility that would allow the fish to adapt to the new environment and set-up a new home site.  Ultimately, the purpose behind why these behavioral traits are prevalent in intertidal fish remains unclear.  The adaptive benefits of these behavioral traits may include enhanced resource usage in the intertidal environment and mitigation of the effects of predation.  For instance, Yoshiyama et al. (1992) speculated that these behaviors allow distribution of individuals over space as to assure food and shelter while keeping mates close at hand.  This would mean that these behavioral traits enable organisms to have populations that are dispersed throughout a location while minimizing competition for resources.

Site fidelity and homing behavior may be influenced by competitive or territorial behavior and a dispersed population would allow for resource availability, such as food, shelter, and/or mates on the individual-level.

**Glossary**

Bimodal respiration – The capacity of an organism to exchange respiratory gases (i.e. $O_2$ and $CO_2$) in both air and water

Census day – A day on which a count is taken of recaptured, tagged individuals for both site fidelity and displacement tests

Displacement – The vector distance from the home site (initial point) to the release site (final point)

Home site – The initial point of capture; in this study, the refuge under which the organism was first located prior to capture

Homing – The ability of an organism to return to a place of former occupation instead of going to other places

In situ – In the natural or original location or environment

Intertidal zone – The region between the high-water mark and the low-water mark; the area between tide marks

Mixed semi-diurnal tide – A tide cycle in which there are higher high & lower high and higher low & lower low tides occurring nearly every day

Neighboring site – A location within 1.5 meters of the home site; an adjacent site of capture to the home site

Resident intertidal fish – Fish who spend the majority or all of their time in the intertidal zone

Site fidelity – The behavior whereby an organism repeatedly returns to a particular site or range for a given period of time

Spatial mapping – The behavior by which an organism produces a cognitive map of an area or location, either through geographical or chemical cues

Stichaeidae – A family composed of about 65 marine species found exclusively in the Northern Hemisphere at various depths from the intertidal to 700 meters, and is characterized by taeniform morphology with a small mouth, thoracic pelvic fins, and a long dorsal fin.

Taeniform – Ribbon-like or eel-like in form; elongate and compressed

Thoracic – Pertaining to the thorax or chest

Tide – The rising and falling of sea level due to the gravitational forces of the sun and moon upon the earth

Visitor intertidal fish – Fish who regularly enter and leave the intertidal zone with the high tides

**Tables**

Table 1: Tagging dates and distinction between designated groups of displaced fish and duration of displacement tests. Fish released at displacements of 0 m were released at the home site and are considered to be tested for site fidelity.

| Distance displaced (m) | Release site locality | Tag color | Tag dates | Test duration (days)[1] |
|---|---|---|---|---|
| 0 | Varied[2] | Yellow | July 7th, 2012 | 40 |
| 10 | South | Blue | July 18th-19th, 2012 | 29 |
| 30 | South | Green | July 21st-22nd, 2012 | 26 |
| 50 | South | White | July 19th-20th, 2012 | 28 |
| 150 | East | Red | July 3rd-4th, 2012 | 44 |

[1]Total test duration for each displacement distance includes both tagging and census days

[2]Location of release corresponded with initial capture site

Table 2: Recapture frequency of displaced *X. atropurpureus* with respect to the home sites and their corresponding neighboring sites. Fish released at displacements of 0 m were released at the home site and are considered to be tested for site fidelity.

| Distance (m) | Number of censuses[1] | Number of displaced fish | Number recaptured at | |
|---|---|---|---|---|
| | | | Home site | Neighboring site[2] |
| 0 | 8 | 15 | 2 (13%) | 3 (20%) |
| 10 | 6 | 5 | - | - |
| 30 | 5 | 5 | - | 1 (20%) |
| 50 | 5 | 5 | - | - |
| 150 | 10 | 5 | - | - |

[1] Maximum number of census dates post-displacement. The number of subsequent census dates was smaller for fish displaced after the initial displacement date.

[2] Fish were considered to be in a neighboring site when recaptured within 1.5 meters of their home site

Table 3: Maximum number of days required for *X. atropurpureus* to home back to either the home site or a neighboring site after initial displacement. Fish released at displacements of 0 m were released at the home site and are considered to be tested for site fidelity.

| Distance displaced (m) | Time interval after initial displacement | | | |
|---|---|---|---|---|
| | 1 day | 11 days | 15 days | 28 days |
| 0 | 1 | 2[1] | - | 2 |
| 10 | - | - | - | - |
| 30 | - | - | 1 | - |
| 50 | - | - | - | - |
| 150 | - | - | - | - |

[1]Both fish were recaptured at their home sites

**Figures**

Figure 1: *Xiphister atropurpureus*. Note the two dark bars with white edges that radiate from behind the eyes and the diminutive pectoral fins.


Figure 2: Google Earth overhead image of South Cove, Cape Arago State Park, Oregon. The site fidelity and homing behavior tests were conducted primarily on the west shore (blue) on an experimental area of approximately 180m (North-South) by 20m (East-West).

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