Mitigating shoreline development: introducing synthetic structures to improve largemouth bass (*Micropterus salmoides)* angling success

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Abstract

Declines in coarse woody habitat (CWH) are of increasing concern to recreational fisheries as shorelines continue to become developed for residential and commercial purposes. CWH is utilized by species of many trophic levels, including top aquatic predators like the largemouth bass (*Micropterus salmoides*). Largemouth bass tend to use CWH as aggregating structure, feeding habitat, and nesting substrate. The objective of this research is to explore how introducing synthetic structures intended to mimic CWH affects catch rates in areas that lack true CWH. This was achieved by using systematic angling and fin clipping to measure and compare catch-per-unit-effort (CPUE) and incidence of recapture of largemouth bass across different habitat types in a northern Michigan lake. Statistical testing revealed a significantly higher CPUE in exposed shoreline after synthetic CWH structures were introduced. Data analysis revealed a significantly higher incidence of recapture in true CWH sites compared to exposed shoreline with or without introduced synthetic structures. Results also indicate that introducing synthetic CWH can have a significant effect on angling success in areas that lack true CWH. While CPUE was similar across true CWH and synthetic CWH sites, *M. salmoides* showed a lower degree of site loyalty at synthetic sites, suggesting that angling effort was distributed over a larger group of individuals than at true CWH.

Introduction

Largemouth bass (*Micropterus salmoides*) are one the most sought after and economically valuable game fish in North America (Chen et al 2003; Pullis and Laughland 1999; Department of Fisheries and Oceans Canada 1998). Excluding Alaska, *M. salmoides* are present in every region of the continental U.S., and states have introduced harvest regulations in attempt to manage healthy populations of this species. Largemouth bass are more likely to be regarded as a trophy species than table fare relative to other freshwater game fish, and therefore are more frequently subject to voluntary catch-and-release by anglers (Sutton 2010). While this means that the fish are generally returned to the water, high pressure angling can still have negative effects on *M. salmoides* nesting and recruitment.

M. salmoides are an aggregating species (Essington and Kitchel 1999) that have been shown to keep a small home range relative to other freshwater game fish (Lewis and Flickinger 1967). The maximum home range of *M. salmoides* is between 0.3 and 1.4 hectares, with a primary range of 0.35 to 0.4 hectares (Winter 1977). Most largemouth bass stay between the shore and 3 meters below the surface within the littoral zone (Winter 1977). Littoral zones are the close-to-shore areas where the photic zone incompasses the entire water column. Littoral zones typically influence most of the fish, macroinvertebrate, and macrophyte assemblages in limnetic ecosystems (Winfield 2004).

M. salmoides home ranges that contain coarse woody habitat (CWH) tend to have a smaller area, as they provide largemouth bass higher concentrations of aggregation zones for feeding and nesting (Ahrenstorff et al. 2009). Coarse woody habitat is defined as fallen trees from the riparian zone (interface between land and water) that offer littoral structure for prey fish refuge, substrate for invertebrate production, and habitat for nesting fish (Lawson et al. 2011). In addition to providing feeding and nesting opportunities, *M. salmoides* are less likely to experience nest predation in the presence of CWH and aquatic vegetation compared to exposed shorelines (Olson et al. 2011).

M. salmoides depend on aggregation structures like CWH for both feeding and reproductive success (Ahrenstorff et al 2009; Savino and Stein 1989; Lawson et al. 2011). As a visual predator, *M. salmoides* prefer ambush predation in the presence of CWH and active searching in the presence of exposed shorelines (Ahrenstorff et al 2009; Savino and Stein 1989). Compared to active searching, ambush predation limits energy expenditure, which allows *M. salmoides* to grow faster and more robust (Sass et al. 2006). For largemouth bass, aquatic prey diversity and abundance tends to increase in areas with high CWH, which leads to a lower reliance on terrestrial prey (Sass et al. 2006). *M. salmoides* also tend to build nesting sites in areas of high CWH (Lawson et al. 2011). Nesting males use sunken logs in CWH sites to block off edges of nests from ovivorous predators, as well as use fallen woody debris, such as bark or sticks, as structure when building nesting sites.

The presence of CWH in freshwater lakes is threatened by lakeshore development from residential property, parks, and roadways (Gaeta et al. 2014; Lawson et al. 2011; Christensen et al. 1996). These developments lead to removal of standing trees in the riparian zone that would naturally fall into the littoral zone. Shoreline development may also lead to the intentional removal of CWH to create swimming beaches or reduce boating obstructions. Decreases in CWH are linked to *M. salmoides* experiencing lower consumption rates, lower growth rates, and more exposed nesting sites (Lawson et al. 2011; Ahrenstorff 2008; Roth et al 2007), which could potentially lead to decreased survival and fitness for this species.

One solution to the issue of declining CWH is the introduction of synthetic aggregation structures (Barwick et al. 2004; Winfield 2004; Rogers and Bergersen 1999). There are several types of synthetic structures commercially available for managing and improving recreational fisheries, most mimicking CWH or floating vegetation. Studies have shown that introducing various synthetic structures to recreational fisheries may improve catch rates (Barwick et al. 2004; Rogers and Bergersen 1999), but the extent of *M. salmoides* site loyalty in areas of synthetic CWH has not been compared to true CWH.

In this study, we investigate how introducing synthetic CWH to exposed shoreline habitat will affect angling success. We also aim to determine whether there is a relationship between habitat type and site loyalty by using the methods of systematic angling and fin clipping. We predict that introducing synthetic structures to exposed shoreline will significantly increase catch-per-unit-effort (CPUE) in selected sample sites. We also predict that higher incidences of recapture will occur in synthetic and CWH sample sites.

Methods

Study Sites

This study was conducted on Bay Lake, located inside the University of Notre Dame Environmental Research Center (UNDERC) in southern Gogebic County, MI. All trials were conducted during a six-week time frame from early-June to mid-July, 2018. Bay Lake is a private, northern temperate lake surrounded by a riparian zone of mostly conifers. The lake has accumulated CWH without removal or major lakeshore development, making it an ideal site for this study. Bay Lake has a surface area of 63.7 hectares, and a maximum depth of 12.0 meters. *M. salmoides* is a top predator species in Bay Lake, although there is also a smaller population of smallmouth bass (*Micropterus dolomieu*; Sass et al 2006). Bay Lake has a shoreline development value (D_L) of 2.64 (UNDERC 1997). Most of the shoreline appeared to contain some degree of emergent or floating vegetation, primarily *Nymphaea* or *Apium* spp.

Three distinct study areas were established using a grid system and random number generator. The areas were at least 150 meters apart, to ensure that three fairly distinct populations of largemouth bass were sampled. Snorkeling was used to evaluate the shoreline of each area and differentiate coarse woody habitat from exposed shoreline. CWH sites contained at least three partially or fully submerged CWH logs within 30 meters of shoreline. CWH logs had to be at least 12.0 cm in diameter and 150.0 cm in length. Each CWH log had to contain at least eight distinct branches 5.0 cm in diameter and 60.0 cm in length. These dimensions were later replicated when constructing synthetic CWH structures. Exposed sites were defined as a continuous 30 meters of shoreline lacking any logs that fit the parameters above. One exposed site at each study area was randomly assigned for placement of synthetic structures. Each study area contained one CWH, one exposed, and one synthetic CWH site (Figure 1). Each of the nine total sample sites contained 30 meters of shoreline, and were at least 50 meters apart from one another.

Synthetic structures

To assess how *M. salmoides* respond to introduced synthetic structures that mimic CWH, we constructed nine artificial logs using polyvinyl chloride (PVC) pipes. The pipe making up the main log was filled with gravel and capped off to avoid structures floating away, but pipes making up the branches were left hollow to encourage prey fish species to occupy the structures. The main log was made from pipe with an outer diameter of 12.0 cm, cut into 150.0 cm lengths. Each log contained eight branches, each 5.0 cm in diameter and 150.0 cm in length. Branches were alternately offset in 45° angles. Three structures were placed in each of the three exposed sites selected for introducing synthetic CWH at a depth of 1.0 meter.

Data collection

The primary sample method used in this study was systematic angling. All nine sites were consecutively sampled a total of 30 times, with 15 morning (06:00 to 09:00) and 15 evening (18:00 to 21:00) trials. The trials began five days after introducing the synthetic structures to allow familiarization to occur. Each site was sampled by a casting continuously for

10 minutes throughout the entire 30 meter shoreline. The timer stopped whenever a fish was brought into the boat and resumed after the fish was returned to the water. Three different artificial lures were used: the Northland Reed-Runner Spinnerbait™, YUM Dinger™, and Heddon Torpedo™. One lure was assigned for each of the 30 rounds of sampling and was used for the entire duration of each round; each lure was used for a total of 10 rounds. Fin clipping was used to differentiate each sample site and measure recapture rates. Each of the three sample areas were assigned a fin (left pelvic fin, right pelvic fin, anal fin). *M. salmoides* captured in CWH, exposed, and synthetic sites were given top, middle, and bottom fin clips, respectively. For example, largemouth bass caught in the synthetic site in the southernmost study area would be clipped at the bottom of its anal fin.

Data analysis

All statistical analyses used SYSTAT Version 13 (Systat Software, San Jose, CA). Because the sampling methods in this study targeted *M. salmoides*, incidental catches of other species were not reflected in the data. Catch-per-unit-effort (CPUE) was defined as:

$$CPUE_i = (C_i / E_i)$$

where C_i = the number of largemouth bass caught, and E_i = total angling effort during the trial span of ten minutes. A one-way ANOVA was used to test for significance between habitat types and CPUE at each of the nine sample sites. Another one-way ANOVA was used to test for significance between habitat type and total recaptures at each sample site. A least mean linear regression was used to determine whether incidence of recapture is dependent on CPUE.

Results

A total of 225 largemouth bass catches were recorded throughout the 30 trials of this study. CPUE was averaged at each of the nine sample sites. The ANOVA test relating CPUE and site type indicated that a significant difference was present ($R^2 = 0.9413$, df = 2, $F = 23.3265$, $p = 0.0014$; Figure 2). An additional Tukey's post-hoc test revealed that CPUE was significantly different between CWH and exposed sites ($p = 0.0022$) and between synthetic and exposed sites ($p = 0.0029$). A significant difference in CPUE was not present between CWH and synthetic sites ($p = 0.9510$).

Fin clipping data showed that 184 of 225 largemouth bass caught were original catches. Incidence of recapture was measured as total recaptures at each study site. The second ANOVA test showed that incidence of recapture was significant different between site types ($R^2 = 0.9304$, df = 2, $F = 19.337$; $p = 0.0024$, Figure 3). An additional post-hoc test displayed significant differences in recapture between CWH and exposed sites ($p = 0.0025$) and between CWH and synthetic sites ($p = 0.0084$). However, there was an insignificant difference in recaptures between synthetic and exposed sites ($p = 0.4595$). The linear regression showed an insignificant relationship between incidence of recapture and CPUE among sample sites ($R^2 = 0.2799$, df = 1, $p = 0.143$; Figure 4).

Discussion

With the amount of CWH declining in many lakes, anglers are more likely to focus on whatever remaining CWH is readily visible. Concentrated angling effort can put high pressure on aggressive nesting males that are more susceptible to angling (Suski and Philipp 2004). Even if nesting males are caught and released, the exhaustive exercise induced by angling is likely to negatively impact the locomotive ability to fend off nest predators for an extended period of time (Suski and Philipp 2004; Cooke et al. 2000; Philipp et al, 1997). Some jurisdictions have implemented angling restrictions to protect spawning *M. salmoides* males, sometimes closing off bodies of water to angling during the spawning season (Noble and Jones 1999). Data from this study suggests that introducing synthetic structures to exposed shoreline increases CPUE without increasing incidence of recapture. A lower site loyalty in this habitat type would suggest that fishing in areas dominated by synthetic structures distributes angling pressure over a greater population of individual largemouth bass, which may improve reproductive success and limit post-angling mortalities.

The presence of significantly higher catch rates when synthetic structure is introduced to exposed shoreline (Figure 2) indicates that such structures can be effective tools for managing and improving recreational fisheries. While CWH and synthetic sites were shown to have very similar catch rates, there were significantly less recaptures at synthetic sites (Figure 3). This provides insight on the different ways in which largemouth bass are using these habitat types. Site loyalty was relatively high in CWH sites, which suggests *M. salmoides* are more likely to include CWH in home or primary ranges. High incidence of recapture in CWH sites also suggests that primary or utilized ranges that contain CWH are smaller in size, causing certain individual *M. salmoides* to be more vulnerable to angling when CWH is targeted.

Different predation styles may explain why CPUE increased significantly when synthetic structures were introduced to exposed shoreline sites. Synthetic structures were constructed to mimic CWH, in which largemouth bass tend to prefer ambushing their prey while concealed by structure (Ahrenstorff et al 2009; Savino and Stein 1989). If synthetic structures allowed for easier ambush predation in introduced sites, *M. salmoides* may have been more likely to aggregate around these synthetic structures, therefore increasing CPUE at sites where synthetic structures were introduced.

One possible explanation for incidence of recapture appearing independent of CPUE is the short duration of the study. All of the data in this study was collected over a six week period in early summer. A study of this length may not have allowed enough time for *M. salmoides* to incorporate synthetic sites into their primary range. If largemouth bass explain why site loyalty was fairly similar between exposed sites and synthetic sites. Although increasing synthetic sites were shown to significantly increase CPUE, the low incidence of recaptures at synthetic sites indicates that individual *M. salmoides* are occupying these sites less regularly than CWH.

While introducing synthetic structures appears to increase *M. salmoides* aggregation in exposed shoreline habitat, PVC structures are unlikely to support the same level of trophic complexity as true CWH. CWH has been shown to increase inorganic sediment retention, which may increase production by supporting higher levels of epipelic algae (Hilton et al. 1986; Vadeboncoeur and Lodge 2000). Predatory fish species, such as *M. salmoides*, rely on healthy populations of benthic invertebrates and small fish species that find refuge in CWH (Vander Zanden and Vadeboncoeur 2002; Savino and Stein 1982). Because PVC does not decompose or accumulate biofilm at the same rate as CWH (Storry et al 2006), introducing synthetic structures cannot satisfy all of the conditions *M. salmoides* require from true CWH in the short-term. Therefore, introducing synthetic structures to recreational fisheries should not be considered a substitute for true CWH. Instead, synthetic structures can be used as supplemental tools that may increase CPUE of recreational fisheries experiencing shoreline development and subsequent loss of CWH.

Future studies interested in exploring how *M. salmoides* use habitat containing synthetic structures are urged to allow more time to pass after introducing structures prior to sampling. If structures are introduced prior to spawning season, the viability of synthetic structures to attract nesting activity may be assessed and compared to natural CWH, providing more insight on how *M. salmoides* use introduced structure. Allowing more time for sampling may also reveal whether *M. salmoides* eventually incorporate synthetic structures into their primary range or whether site loyalty remains relatively low. It may also be worth exploring how introducing synthetic CWH structures affects catch rates in lakes with both high and low amounts of true CWH.

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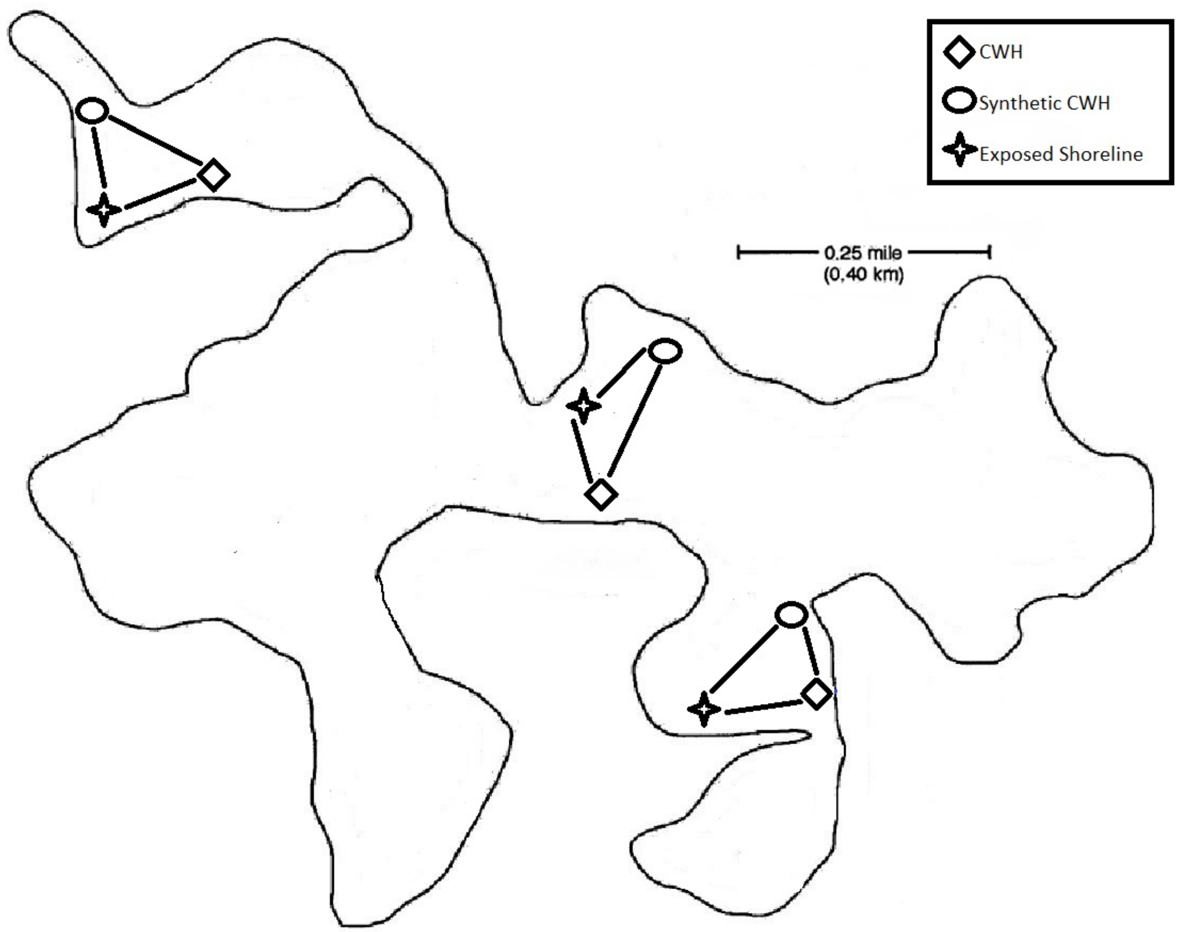

Figure 1. A map of Bay Lake, with all nine sites denoted by shapes. The three distinct sample areas are connected and represented by thick black lines.

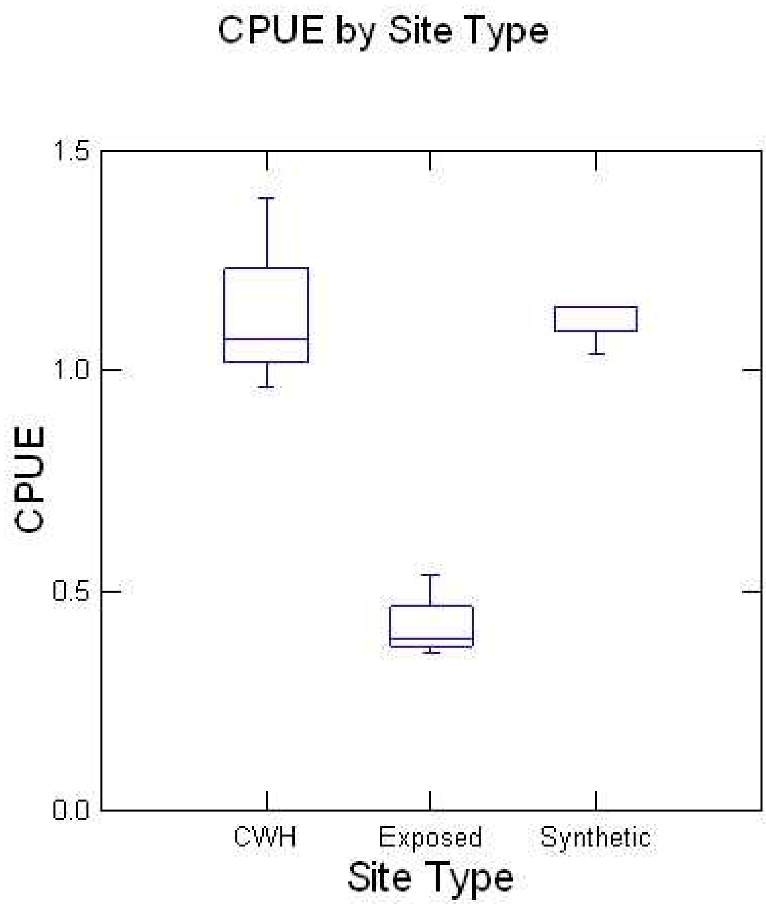

Figure 2. One-way ANOVA test shows a relationship between CPUE and CWH, Exposed, and Synthetic CWH habitat types. Exposed habitat type has a lower CPUE compared to CWH and synthetic CWH (df = 2, p = 0.0014, n = 9).

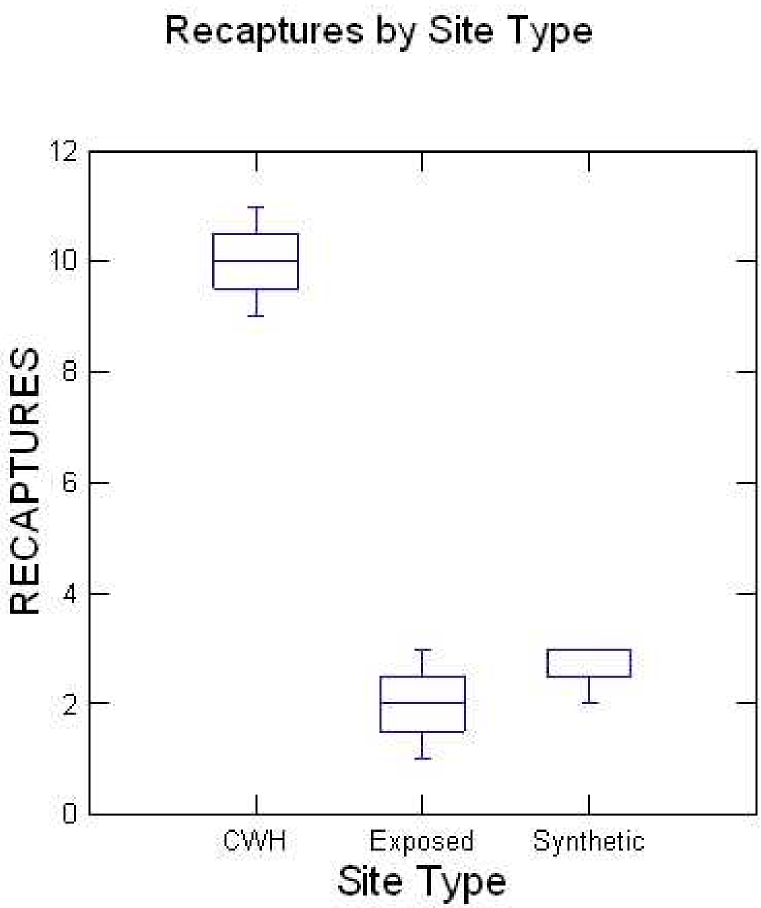

Figure 3. One-way ANOVA test shows a relationship between incidence of recapture and CWH, Synthetic CWH, and exposed habitat types. CWH type has a higher incidence of recapture compared to Synthetic CWH and Exposed (df = 2, p = 0.0024, n = 9).

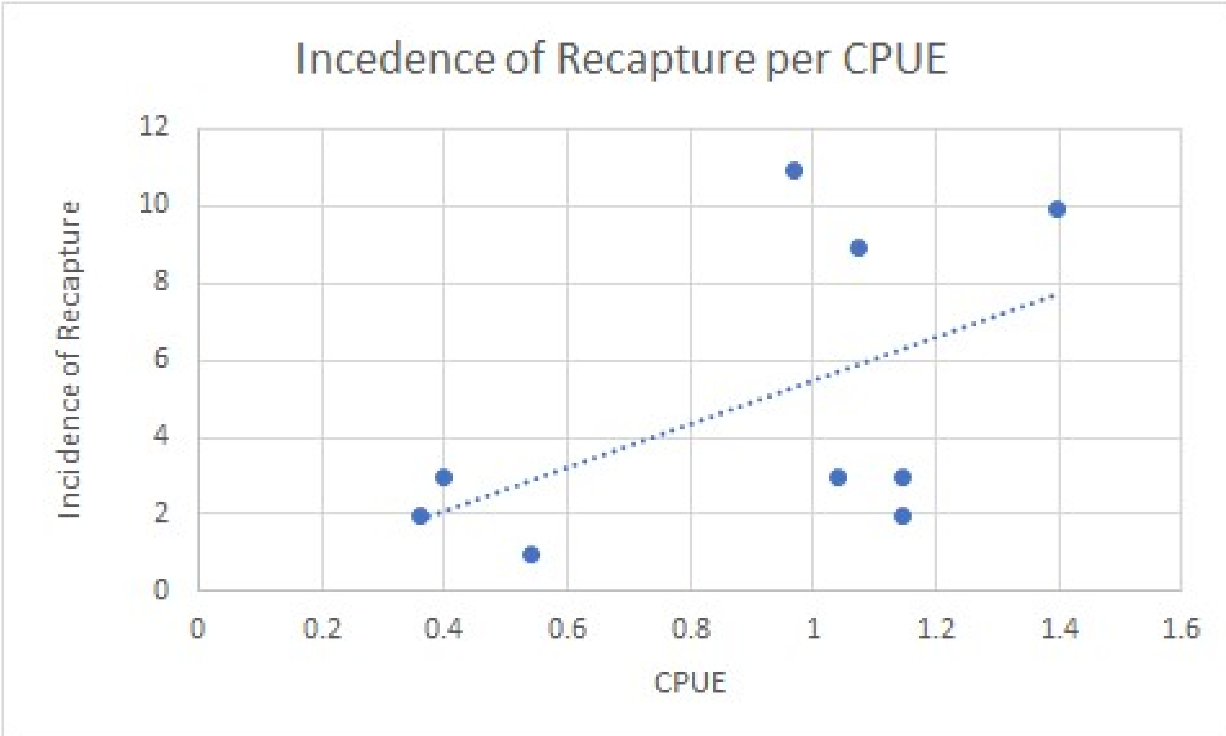

Figure 4. Incidence of recapture was not correlated to CPUE ($R^2 = 0.2799$, df = 1, $p = 0.143$, n = 9).