Substrate's effect on the establishment of rusty crayfish (Orconectes rusticus)

Sam Pecoraro

BIOS 35502: Practicum in Field Biology

Advisor: Ashley Baldridge

2009

ABSTRACT:

The rusty crayfish is a well-studied invasive that has become a common sight in Northern Wisconsin and the Upper Peninsula of Michigan. Likely a result of human error, the negative effects of this species' invasion can be dramatic. Rusty crayfish have been found at very different densities in two lakes associated with UNDERC property. One is a large, public access lake and the other, only two kilometers away, is a small, very limited access lake. Given the important influence substrate, especially cobble, can have on the population dynamics and establishment of this species, I predicted that the substrates of the two lakes would be different. Statistical testing of visual substrate characterization from three depths revealed that the substrates of the two lakes were indeed dissimilar. I also expected there to be a statistically higher numbers of crayfish in the preferred, cobble habitat. Statistical tests revealed that there were no significant associations between the number of crayfish captured from trapping and hand collection with substrate as a main effect. Though my results were not completely as expected, the differences in substrate between the two lakes have important conservation implications for UNDERC.

INTRO:

Rusty crayfish (*Orconectes rusticus*) have become a common invasive species on northern temperate lakes over the past 50 years. They may have been introduced by the emptying of anglers' bait buckets, commercial crayfish harvesters, or property-owners trying to rid their lakes of weeds (Wilson et al. 2004). However benign the intentions of their introducers, the negative impacts of *O. rusticus* on lake ecology have been long-studied and well documented (e.g., destruction of macrophytes, Lodge and Lorman 1987; Hanson and Chambers 1995; Nystrom and Strand 1996 ; Rosenthal et al. 2006; reduction of macroinvertebrates, Wilson et al. 2004, McCarthy et al. 2006; displacement of other crayfish, Olsen et al. 1991, Hill and Lodge 1994). Rusty crayfish are such a proficient invasive because they typically out-compete and replace the native species of crayfish *O. propinquus* and *O. virilis* (Hill and Lodge 1994). They are then able to persist at abundances much higher (between 2-18 times as many crayfish per trap) than their native counterparts for as long as ten years, which can have whole food web implications (Wilson et al. 2004).

Substrate plays an important role in crayfish dynamics, especially species establishment. According to Wilson et al. 2004, the availability of a cobble habitat is an essential factor influencing *O. rusticus* establishment. Predation risk for smaller crayfish tends to be lower in cobble habitats than in sand, muck or macrophyte habitats because there is more debris for them to take refuge in (Kershner and Lodge 1995). Additionally, cobble habitats are preferred by female crayfish as nurseries (Lorman 1980). Rusty crayfish are able to displace the other two species of crayfish from the preferential cobble habitat during the day when predation risk is highest and cover is most important (Hill and Lodge 1994).

Orconectes rusticus have been discovered in two lakes on UNDERC property, but seem to be establishing at much different rates. These two lakes provide a unique opportunity to study the population dynamics of an important invasive species. Data from the Lodge Lab indicate that while *Orconectes rusticus* has been in Brown Lake for at least 5 years, it is only persisting at relatively low population densities. One mature female was trapped at location 10 in Brown Lake in 2004, but none were captured over the next four years. However, in July 2008, two male rusty crayfish were captured at trap location 10. Both rusty crayfish had carapace lengths over 40mm, indicating that they are at least Age 3. This is interesting, as it indicates that the Rusty crayfish population is persisting, but below the requisite threshold for trapping.

In Big Lake, which is only about two km (as the crow flies) from Brown Lake, *Orconectes rusticus* has existed since at least 1995. Rusty Crayfish have since taken over in Big Lake, with trap catches up 24males/trap. No other species of crayfish has been recorded in Big Lake since the Lodge Lab started logging data in 2003.

Given the differences in populations of rusty crayfish between the lakes, I hypothesize that there will be significant differences between the substrates in Brown and Big Lakes, with Big containing a higher percentage of the preferred cobble habitat. Additionally, since Rusty crayfish have reached the epidemic proportions (>9 crayfish/trap) as described by Wilson et al. 2004, I believe Big lake will have higher numbers of *O. rusticus* in all substrate types, with especially high concentrations in the cobble.

METHODS:

I compared the substrates of both Brown and Big Lakes. There was a good amount of data on the substrate of Big Lake from a previous characterization by Brett and Jody Peters in 2007, so I mapped the littoral zone of Brown Lake for comparison. I categorized the substrate as cobble, sand, macrophyte, or muck. Visual substrate classification in Brown Lake was taken every 50m along the shoreline from GPS data (41 points). Following the protocol set by the Peters' in 2007, I characterized substrate in Brown at three different depths: 0.75m, ½secchi, and ¾secchi. Secchi depth on the Big Lake data was measured to be 2.4m in 2007. My data on Brown Lake calculated secchi depth at 2.14m. A view box and/or an oar were used in deeper water to quantify the substrate.

To assess current crayfish densities in both lakes for use in conjunction with the substrate data, both hand collection and trapping techniques were used in both Brown and Big lakes at three substrate types: cobble, sand, and macrophyte. No trapping nor hand collection occurred in muck because crayfish so rarely inhabit such areas. The areas were selected from the substrate characterization with three plots of each substrate type for a sample size of nine. Hand collection was performed in $0.25m^2$ quadrats set up randomly throughout areas of same substrate type (four quadrats per substrate type per lake). Crayfish traps (modified Gee minnow traps) were then set with 120g beef liver as bait in the same substrate areas used for quadrat counting. Two traps were set in each of the three substrate types per lake. Traps were needed because they tend to selectively catch larger male crayfish, whereas hand counting more frequently catches females. Species, carapace length, sex, and form were determined on captured crayfish. Crayfish quadrat data was not used due to the large numbers without a capture in Brown Lake and due to the relatively low numbers from Big Lake hand collection data. Trapping data was averaged from the two trap catches at any one plot. To continue the monitor trapping that helped make this research possible, Brown Lake was trapped a second time at 20 trap locations. A Kruskal-Wallis ANOVA test was performed using SYSTAT 12 software to test for variation in crayfish catches with substrate as a main effect. I followed up with a Friedman Analysis of Variance with sex and substrate as factors. Contingency analysis was performed in R (version 2.8.1) to see if substrate distribution is independent of lake.

RESULTS:

The substrates of Big and Brown Lakes were widely disparate. The breakdown for Brown Lake was: 6% cobble, 71% vegetation, 14% sand, and 9% muck. Big Lakes' breakdown: 31% cobble, 12% vegetation, 36% sand, and 21% muck (Fig. 1). The χ^2 results showed that substrate distribution is not independent of lake (χ^2=73.61, df=3, $p<0.001$) (Fig. 5).

The trapping data was incontrovertibly different between the two lakes. One *O. virilis* was captured during hand collection from Brown Lake and seventeen *Orconectes rusticus* were collected on Big Lake's quadrat searches. One *O. virilis* was trapped on Brown Lake; 493 *O. rusticus* were trapped on Big Lake (Fig. 2). Of the crayfish found on Brown Lake, one was a male found in a cobble habitat and one was a female found in sand with carapace lengths of 25mm and 43mm, respectively. Big Lake had 149 males and 361 females plus 5 individuals that escaped from hand collection before we had the chance to sex them. The average carapace length for the rusty crayfish in Big Lake was 29.7mm ± 0.2mm SE.

The ANOVA that tested for substrate's effect on number of crayfish caught from the combined quadrat and trapping data was only performed on data from Big Lake because of insufficient data for Brown (only two crayfish caught total). Shapiro-Wilk and Levene tests for normality were run simultaneously with the ANOVA, and revealed that the data violated the assumptions of the test. The results of the subsequent Kruskal-Wallis test showed that there was no statistically significant difference between the amount of crayfish caught in any one substrate type (K-W=2.00, df=2, p=0.368; Fig. 3). One of the replicates from the macrophyte substrate was a possible outlier with 71.5 average captures vs. 0.5 and 1.5 captures for the other two macrophyte replicates respectively. The next highest average capture for any one replicate had a cobble substrate and had 39.5 crayfish. When the possible outlier was removed and the K-W Analysis of Variance was run again, the results still had no statistical significance (K-W=4.25, df=2, p=0.119).

No difference was found in trap capture by sex. The Friedman test for difference in average trap capture on Big Lake by substrate and sex demonstrated a statistically non-significant trend (Friedman stat.=3.0, df=1, p=0.083; Fig. 4).

DISCUSSION:

My predictions about substrate differences between the two lakes were correct. Contingency analysis revealed that substrate distribution is actually dependent on the lake. Big Lake had a much higher percentage (31%) of the cobble habitat ideal to Rusty crayfish establishment than Brown Lake (6%) (Fig. 1). The macrophyte substrate type, however, was much higher in Brown (71%) than in Big (12%) (Fig. 1). It is important to consider here that though macrophyte habitats may offer some cover from predation for crayfish, they somewhat paradoxically also harbor the very predators that crayfish hide from, fish. The macrophyte communities of Big Lake could also be being altered by the crayfish themselves. According to Wilson et al. 2004, rusty crayfish can significantly reduce macrophyte densities. The sheer amount of vegetation covering the littoral zone of Brown Lake, coupled with the large fish catches my partner Grace Loppnow (Loppnow 2009) and I extracted from fyke and seine netting, leads me to believe that top-down predator control could be a serious factor in *Orconectes rusticus*' inability to flourish in Brown Lake.

Contrary to my predictions, I found that average crayfish captures per site did not differ by substrate in Big Lake (p=0.368; Fig. 3). These results were not as expected. Even when the possible macrophyte outlier was dismissed our results didn't demonstrate even a marginally significant trend (p=0.119). The very high trap catch at the outlying macrophyte site could have been skewed by the substrate on either side of it. Both of the adjacent sites had been characterized as cobble at two of the three classification depths. The close proximity of a cobble substrate, which could serve as a crayfish source, could have influenced the catch in this vegetated area. The small sample size could also be the cause of the unexpected statistical insignificance of our results. A simple average by substrate for Big Lake data showed that while cobble habitat still had the highest average numbers of catches, sandy substrates had higher catches than macrophyte areas (Fig. 3). A small sample size and variation among sites in each substrate type are likely the cause of these counterintuitive results.

Though our statistics showed only a marginally significant trend ($p=0.083$) for differences in sex by substrate, our data shows a large margin between the number of males and females captured in traps on Big Lake. I think we may have trapped at a unique time in the season for crayfish. The overwhelming number of females captured in traps (361) compared to males (149) indicates a possible molt transition in progress. I suspect that we trapped right after gravid females had released their brood. The substantial energy commitment requisite to brooding would have left them starving and the free meal provided by the beef liver in our traps may have been irresistible. The relatively small number of males found in our traps may be related to the fact that we only found form two males in our traps. It is likely that the majority of the males were in the process of molting when we did our trapping. It is hard to qualify this without having trapped Big Lake previously or since we collected our data, but it is nonetheless plausible that all of the males we trapped had just molted from form one to form two. The remaining males were busy molting; this coupled with the theory that the females were brooding explains the unexpectedly high number of females captured in traps.

A high percentage of cobble substrate is paramount to *O. rusticus* establishment according to the literature. Our data doesn't conflict with that when the trapping data is considered alongside the substrate data, though correlation does not necessarily imply causation. The only significant result we obtained- the dependence of substrate on lake, was predicted by my hypothesis. Big Lake's unambiguously higher number of crayfish captures fits within the framework of disparate substrates. It is unfortunate that our data was not normally distributed, and that parametric statistics could not be utilized.

It is important to note that, while we collected no *O. rusticus* during our hand collection and trapping on Brown Lake, in continuing the Lodge Lab monitor trapping that provided the context for our experimentation, we caught a rusty crayfish at trap location 18. This is intriguing because it was on the complete other side of the lake from the trap location 10, the only place where *O. rusticus* has been found.

Rusty Crayfish have been found in Brown Lake over the course of past five years, and we found an additional individual in a new location for the species. Because of a low amount of cobble habitat and high levels of crayfish predators, I am not convinced that the trajectory of the Rusty crayfish in Brown Lake will parallel that of Big Lake. It is important to note that no species of crayfish has been detected at high population densities in Brown Lake, though it's true *O. rusticus* can reach much higher populations than its congeners. The limited access nature of Brown, which reduces the likelihood of additional introductions, and the fact that *O. rusticus* has come no where near epidemic levels leads me to predict that Brown Lake is not likely to sustain high population densities of rusty crayfish.

ACKNOWLEDGEMENTS:

I would like to thank my partner, Grace Loppnow, whose help, support, and camaraderie made this research possible. I would like to thank my mentor, Ashley Baldridge, whose mentorship and hands-on help guided me throughout my work. Thanks to Navit Reid for helping me characterize the substrate of Brown Lake. Thanks to Heidi and Andy Mahon for their advice on my analysis and results and help with quadrat searching. My hat's off to Andrew Perry, Derryl Miller, and Ashley Bozell for also helping me with quadrat searches. I am grateful for the Lodge lab and its monitor trapping records, which gave context to my work and Brett and Jody Peters who made substrate data on Big Lake readily available to me. I would also like to thank the Hank family for making this research program available to undergraduates like myself.

REFERENCES:

Hanson, J.M., and Chambers, P.A. 1995. Review of effects of variation in crayfish abundance on macrophyte and macroinvertebrate communities of lakes. ICES Mar. Sci. Symp. 199:175-182.

Hill, A. M., and D. M. Lodge. 1994. Diel changes in resource demand: competition and predation in species replacement among crayfishes. Ecology 75: 2118-2126.

Kershner, M.W., and Lodge, D.M. 1995. Effects of littoral habitat and fish predation on the distribution of an exotic crayfish, *Orconectes rusticus.* J. North Am. Benthol. Soc. 14: 414-422.

Lodge, D.M., and Lorman, J.G. 1987. Reductions in submersedmacrophyte biomass and species richness by the crayfish *Oronectes rusticus.* Can. J. Fish. Aquat. Sci. 44: 591-597.

Loppnow, G. L. 2009 The impact of fish predation on invasive Rusty Crayfish (*Orconectes rusticus*) populations in two Northern temperate lakes. UNDERC report, University of Notre Dame.

Lorman, J.G. 1980. Ecology of the crayfish *Orconectes rusticus* in northern Wisconsin. Ph.D. thesis, University of Wisconsin-Madison.

McCarthy, J. M., C. L. Hein, J. D. Olden, and M. J. Vander Zanden. 2006. Coupling long-tem studies with meta-analysis to investigate impacts of non-native crayfish on zoobenthic communities. Freshwater Biology 51:224-235.

Nystrom, P., and Strand, J.A. 1996. Grazing by a native and and exotic crayfish on aquatic macrophytes. Freshw. BioI. 36: 673682.

Olsen, T. M., D. M. Lodge, G. M. Capelli, and R. J. Houlihan. 1991. Mechanisms of impact of an introduced crayfish (*Orconectes rusticus*) on littoral congeners, snails, and macrophytes. Canadian Journal of Fisheries and Aquatic Science 48:1853-1861.

Rosenthal, S. K., S. S. Stevens, and D. M. Lodge. 2006. Whole-lake effects of invasive crayfish (*Orconectes* spp.) and the potential for restoration. Canadian Journal of Fisheries and Aquatic Science 63:1276-1285.

Wilson, K. A., J. J. Magnuson, D. M. Lodge, A. M. Hill, T. K. Kratz, W. L. Perry, and T. V. Willis. 2004. A long-term rusty crayfish (*Orconectes rusticus*) invasion: Dispersal patterns and community change in a north temperate lake. Canadian Journal of Fisheries and Aquatic Sciences 61: 2255-2266.

FIGURES:

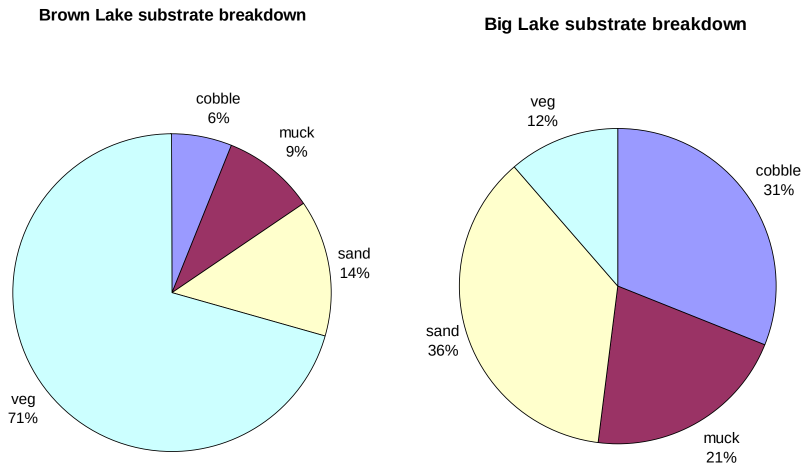

Figure 1.–breakdown of the four substrate types as characterized on Brown Lake in 2009 and Big Lake in 2007. The cobble habitat essential to *O. rusticus* establishment is much more prevalent in Big Lake.

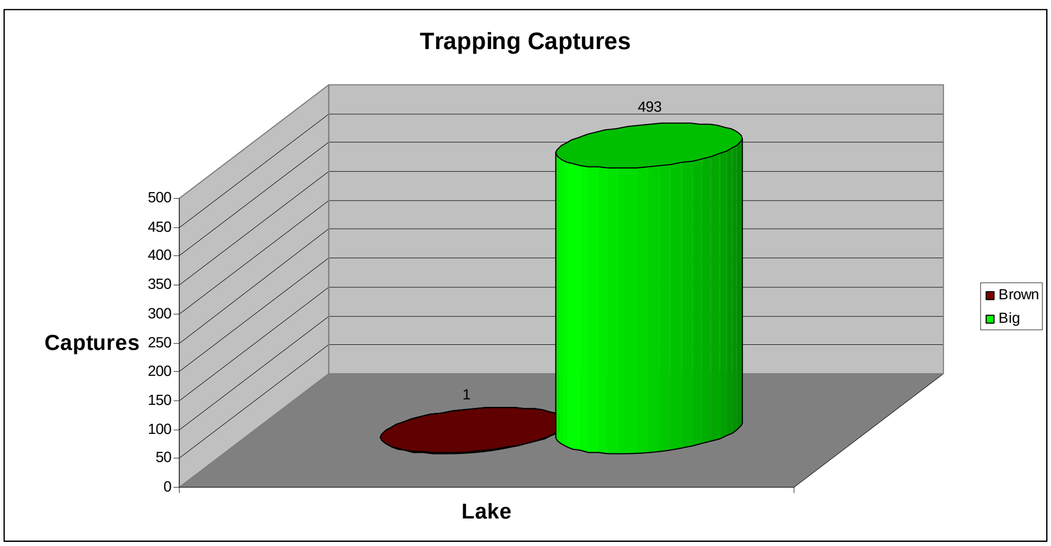

Figure 2.-Crayfish trapping data from Brown and Big Lakes. 18 total traps were set in 9 different locations with three different substrate types in each lake.

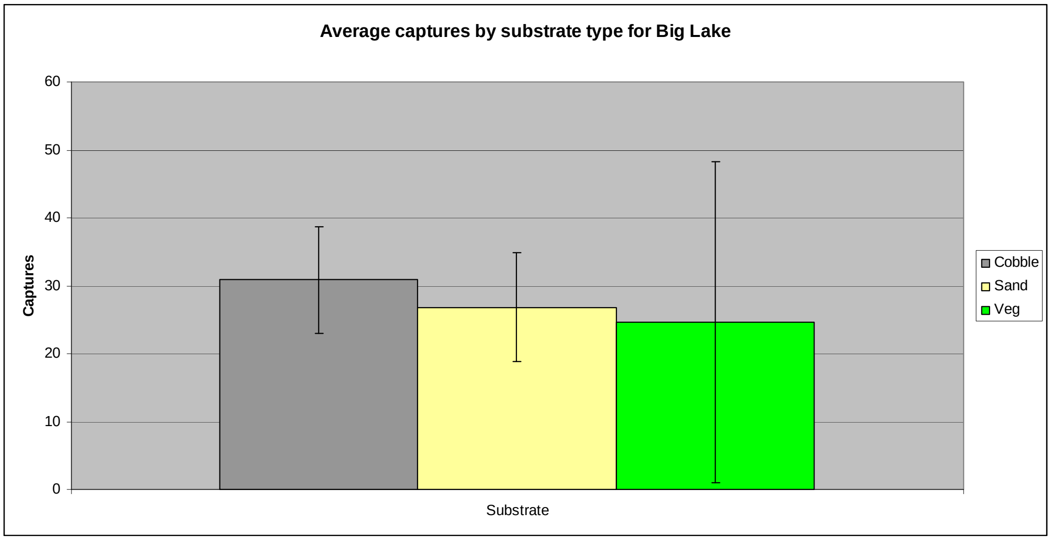

Figure 3.-Distribution of captures on Big Lake by substrate type. Cobble has the highest number of captures, as expected. Sand had more captures than vegetation, however. No results statistically significant (p=0.368).

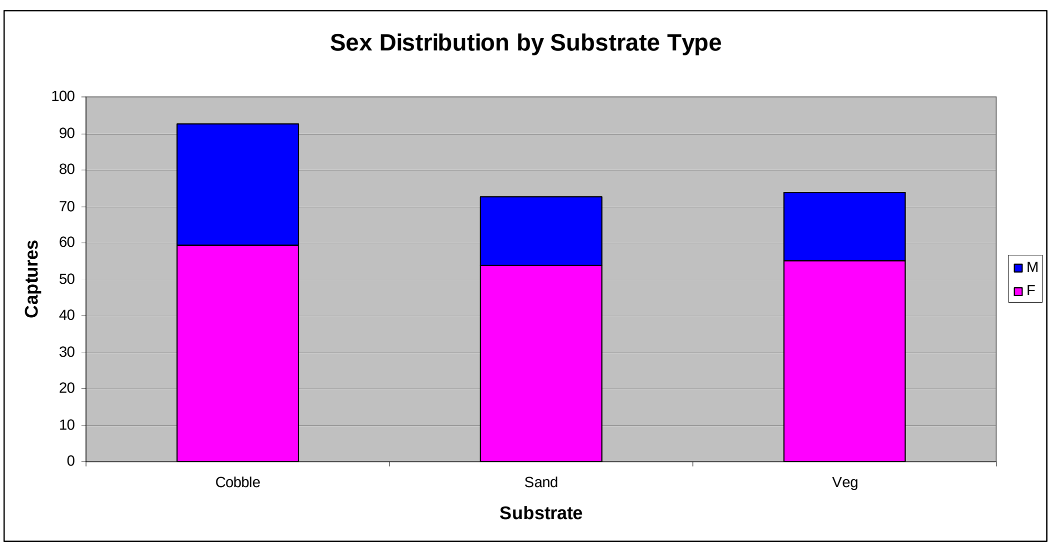

Figure 4.-Distribution of capture by sex and substrate type. These are the sums of the averages at each substrate type Cobble has the highest number of both males and females, though no results statistically significant (p=0.083).

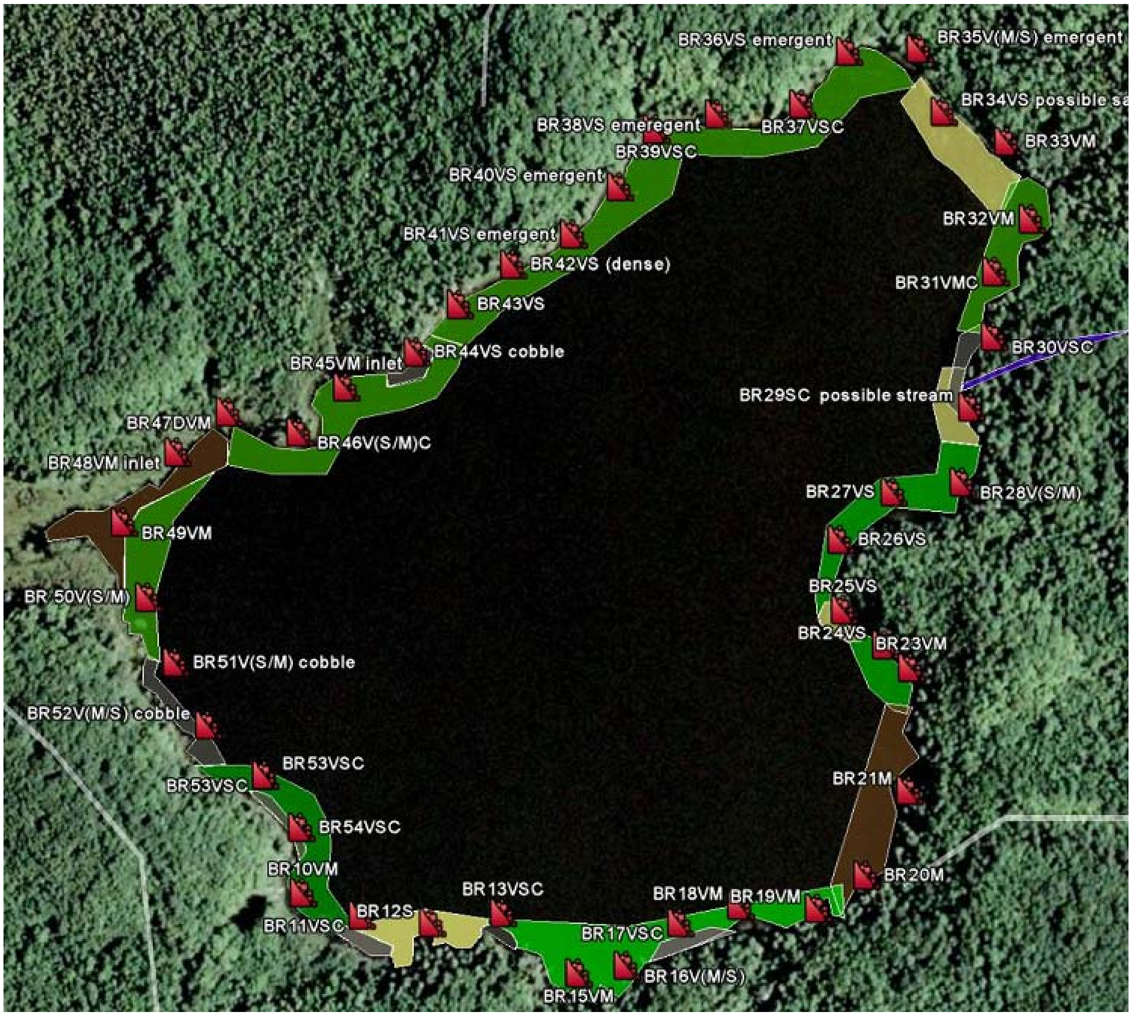

Figure 5.-Substrate map of Brown Lake created in Google© Earth from substrate characterization at three different depths. The substrates of Brown and Big lakes were statistically discrete ($p<0.001$).