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Integrated assessment of oyster reef ecosystem services: Macrofauna utilization of restored oyster reefs

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INTEGRATED ASSESSMENT OF OYSTER REEF ECOSYSTEM SERVICES

5/30/2016

Macrofauna utilization of restored oyster reefs

A final report to:
NOAA Chesapeake Bay Office

Prepared by:
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VIMS | William & Mary
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University of Maryland

Integrated assessment of oyster reef ecosystem services

MACROFAUNA UTILIZATION OF RESTORED OYSTER REEFS

Award Information

Project Title: Integrated assessment of oyster reef ecosystem services: Macrofaunal utilization of restored oyster reefs

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Abstract

Within the Harris Creek Oyster Sanctuary in the Maryland portion of Chesapeake Bay, we evaluated relationships between basic oyster reef characteristics and the abundance and biomass of macrofauna. The eight sites selected for these studies included five restored oyster reef sites and three sites suitable for restoration that had not been restored. These sites encompassed a range of oyster biomass density and were spread throughout the sanctuary area. At each site one month prior to each of four sampling periods, divers filled four wire mesh baskets (0.1m^2 surface area x 15 cm depth) with material from the site and embedded them so that the surface was flush with the surrounding substratum. In spring, early summer, late summer and fall of 2015, divers collected baskets and returned them to the laboratory where all macrofauna ≥1 mm were collected from each sample and their identity, abundance and biomass were determined. In addition to the abundance and biomass of oysters, we also assessed the amount of surface as the volume of live oysters along with that of any oyster shells

whose surface was at least 50% oxic based on coloration (i.e. black shell was presumed to have been buried below the surface in anoxic conditions).

Positive relationships were identified for all three reef characteristics and the three major macrofaunal groups examined. In the majority of seasons, the relationship between both biomass and abundance of the hooked mussel, *Ischadium recurvum*, as a power function of oyster tissue biomass density, oyster abundance per square meter and surface shell volume. The relationship between oyster reef characteristics and the biomass and abundance of the mud crab, *Eurypanopeus depressus*, and of the naked goby, *Gobiosoma bosc*, were always positive but were more variable than that for *I. recurvum*. These data demonstrate that relationships can be found between oyster reef characteristics and macrofauna abundance and biomass. They further demonstrate that, in many cases, simple measures of reef characteristics such as oyster abundance and shell volume can provide predictions of macrofauna abundance and biomass that are comparable to more labor intensive measures such as oyster tissue biomass.

Rationale

Recognition that oyster reefs support diverse and abundant benthic communities has provided one of the primary ecological rationales for preserving and restoring these habitats (Coen et al. 2007), and numerous studies have documented enhancements in these metrics on reefs relative to other estuarine habitats (e.g., Coen et al. 1999, Stunz et al. 2010, Rodney and Paynter 2006, Kellogg et al. 2013). Although enhanced abundance and biomass of macrobenthic organisms on oyster reefs implies enhanced productivity and support of higher trophic levels, direct measurement of secondary production is rarely feasible within the logistic and funding constraints of post-restoration monitoring because of the intensive sampling required. However, several recent studies have used alternate methods of determining secondary production and found that reasonable estimates can be obtained using these techniques, and that secondary production is the most appropriate metric for estimating the food web subsidy provided by structured habitats (French McCay and Rowe 2003, Wong et al. 2011). Although several recent and ongoing studies have characterized macrofaunal communities on restored oyster reefs in Chesapeake Bay (e.g. Rodney and Paynter 2006, Kellogg et al. 2013), these studies have generally focused on reefs or experimental sites with high densities of large adult oysters. At present, little is known about how macrofaunal communities develop over time on subtidal oyster reefs restored using hatchery-produced juvenile oysters settled on adult oyster shell (hereafter “spat on shell”), and secondary production rates for these types of reefs are lacking. Observations suggest that enhancement of secondary production and attendant nutrient sequestration can begin within weeks of planting spat on shell. However, the relationship between these ecosystem functions and reef characteristics such as oyster biomass density and reef topographic complexity are unknown.

The Oyster Metric Workgroup (OMW) has recommended targeted monitoring programs, as well as controlled experiments and modeling studies, as effective ways to evaluate the success of restored oyster reefs. Specifically, the OMW believes that the ability to identify generalizable relationships between easily measured reef characteristics (reef size, oyster abundance/biomass, reef complexity) and the many ecosystem services that oyster reefs provide is crucial to accurate estimation of the ecosystem services provided by the broad range of ongoing oyster reef restoration activities and, in turn, to justifying the expenditure of public funds on these restoration efforts (OMW 2011).

Project Narrative

Our overarching objective was to quantify relationships between oyster restoration and the provision of ecosystem services related to restoration. In this report, we describe the first year of a four-year project focused on characterizing the macrobenthic invertebrate (≥ 1 mm) and small resident finfish communities of restored and unrestored sites in Harris Creek, MD and identifying quantitative relationships between these communities and basic oyster reef characteristics.

Methods

Study sites: All studies were conducted within the Harris Creek Oyster Sanctuary in the Maryland portion of Chesapeake Bay (Fig. 1). Using a variety of techniques, restoration activities have been implemented on >300 acres of historic oyster bottom (i.e. areas identified as viable oyster habitat at some point in the past) within this sanctuary. Within Harris Creek, we studied five restoration sites and three control sites that were suitable for restoration but were not subject to any restoration activities (hereafter “non-restored”). To control for the influence of the restoration method employed, we limited our study to sites where juvenile oysters set on oyster shell (i.e. “spat-on-shell”) were planted directly on the bottom (i.e. areas with substratum conditions suitable for oyster survival and growth without adding hard substrate prior to planting). To control for the influence of oyster age, we selected only sites that were planted in 2012. Prior to site selection, a patent tong survey of potential sites was conducted in 2014 by the Paynter Lab at the University of Maryland. Based upon the resulting data, we delineated eight 1.25-ha study sites for our work (Fig. 2). The selected areas provided biomass densities ranging from 2.7 to 98.4 g dry weight (DW)

Fig. 1. Location of Harris Creek Oyster Sanctuary in the Maryland portion of Chesapeake Bay.

oyster tissue per square meter at the time of initial surveys (Fig. 3). These same study sites were used by two complementary NCBO-funded projects focused on assessing the relationships between oyster biomass density and provision of habitat for macrofauna (Award #: NA13NMF4570208: Integrated assessment of oyster reef ecosystem services: Fish and crustacean utilization and trophic linkages), and biogeochemical fluxes (Award #: NA14NMF4570275: Integrated assessment of oyster reef ecosystem services: Quantifying denitrification rates and nutrient fluxes).

Field sampling: Resident macrofaunal community abundance, diversity, and biomass was determined by sampling attached and mobile macrofauna as well as oysters from each sampling location during each of four sampling periods (spring, early summer, late summer, and fall). For the purposes of this project, we define the resident macrofaunal community as all sessile and mobile organisms retained on a 1-mm mesh. Macrofaunal samples were collected using diver-deployed baskets (0.1 m^2 area x 0.15 m deep, constructed of 1.3-cm vinyl-coated steel wire mesh frame lined fine mesh [≤1mm]. Four baskets were deployed by divers at each site a minimum of one month prior to each sampling period. During deployment, baskets were filled

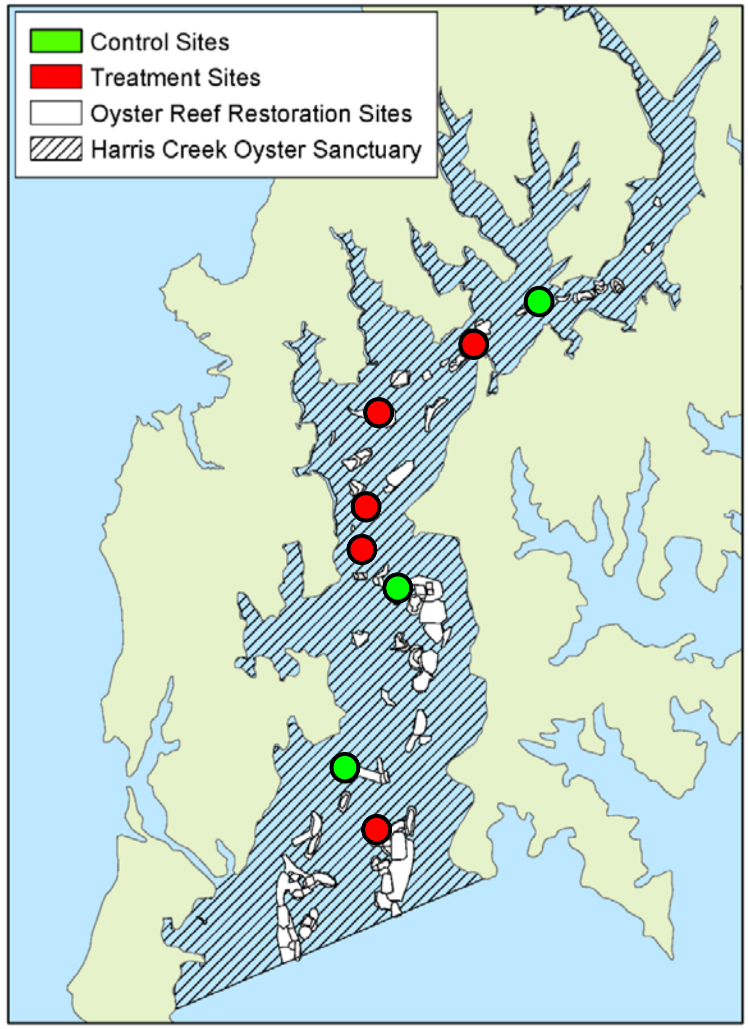

Fig. 2. Location of control (non-restored) and treatment (restored) sites within the Harris Creek Oyster Sanctuary in relation to the larger oyster reef restoration effort (white polygons).

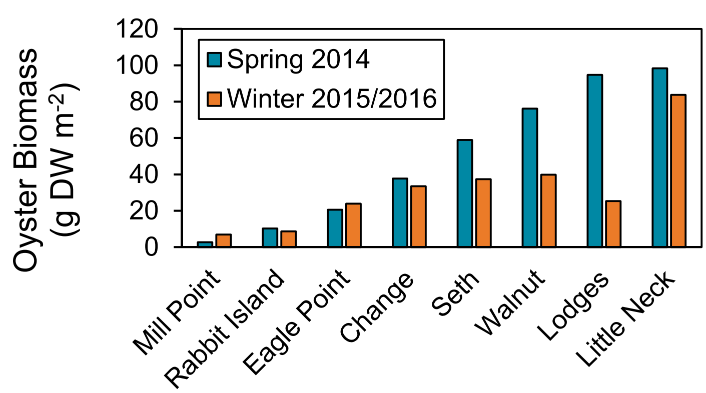

Fig. 3. Oyster biomass density (DW = dry weight of oyster tissue) at study sites based upon patent tong surveys in spring 2014 and winter 2015/2016 (Paynter, unpublished data).

with existing reef material and completely embedded into the reef matrix. To retrieve baskets, divers covered each basket with a fitted lid lined with ≤1 mm mesh. After samples were collected and returned to the boat (Fig. 4), the contents of each basket was bagged to prevent escape of organisms. After all samples were collected, they were transported immediately to VIMS Eastern Shore Laboratory where the contents were thoroughly rinsed through a 1-mm mesh sieve. All macrofauna retained on the sieve or attached to shells were identified to the lowest practical taxonomic level (usually species) and enumerated. Biomass was determined as dry weight and ash-free dry weight for all faunal groups. For oysters and for the hooked mussel, *Ischadium recurvum*, seasonal length to biomass relationships were identified and the resulting equations were used to calculate the biomass of these species based upon length measurements.

Fig. 4. Macrofauna sample basket being brought onboard boat by VIMS staff.

As noted above, the data reported here are the results of the first year of a four-year ongoing project. Here we present the data for organisms that are ≥4 mm for which we are confident this size fraction represents the bulk of both the abundance and biomass of the species. Additional work is ongoing for the smallest size fractions of the samples collected to date as part of a three-year award from NCBO (NOAA Award #: NA14NMF4570287).

Statistical analyses: Because variance was high between replicates within site, the contents of each basket was treated as a subsample and the data were averaged within each site during each sampling season. Linear and non-linear regression analyses were used to identify quantitative relationships between oyster reef characteristics and various components of the macrofaunal community.

Results

A survey of oyster biomass density in Harris Creek was conducted by the Paynter Lab in the winter of 2015/2016 (Paynter, unpublished data), found that, instead of increasing as a result of oyster growth, the biomass density of oysters within several of our sites had declined since the 2014 survey. The proportion of dead oyster shell did not increase significantly between the two sampling periods, suggesting that the declines could not be attributed to disease or burial. Because we no longer had the expected range of biomass density, all analyses were conducted based upon reef characteristics within the sampling basket rather than any reef-scale metrics.

Of the 128 sampling baskets deployed, 124 were collected successfully. The four samples that were not collected successfully were disturbed by unknown activities between the time of deployment and the time of sampling. In all cases, the sampling

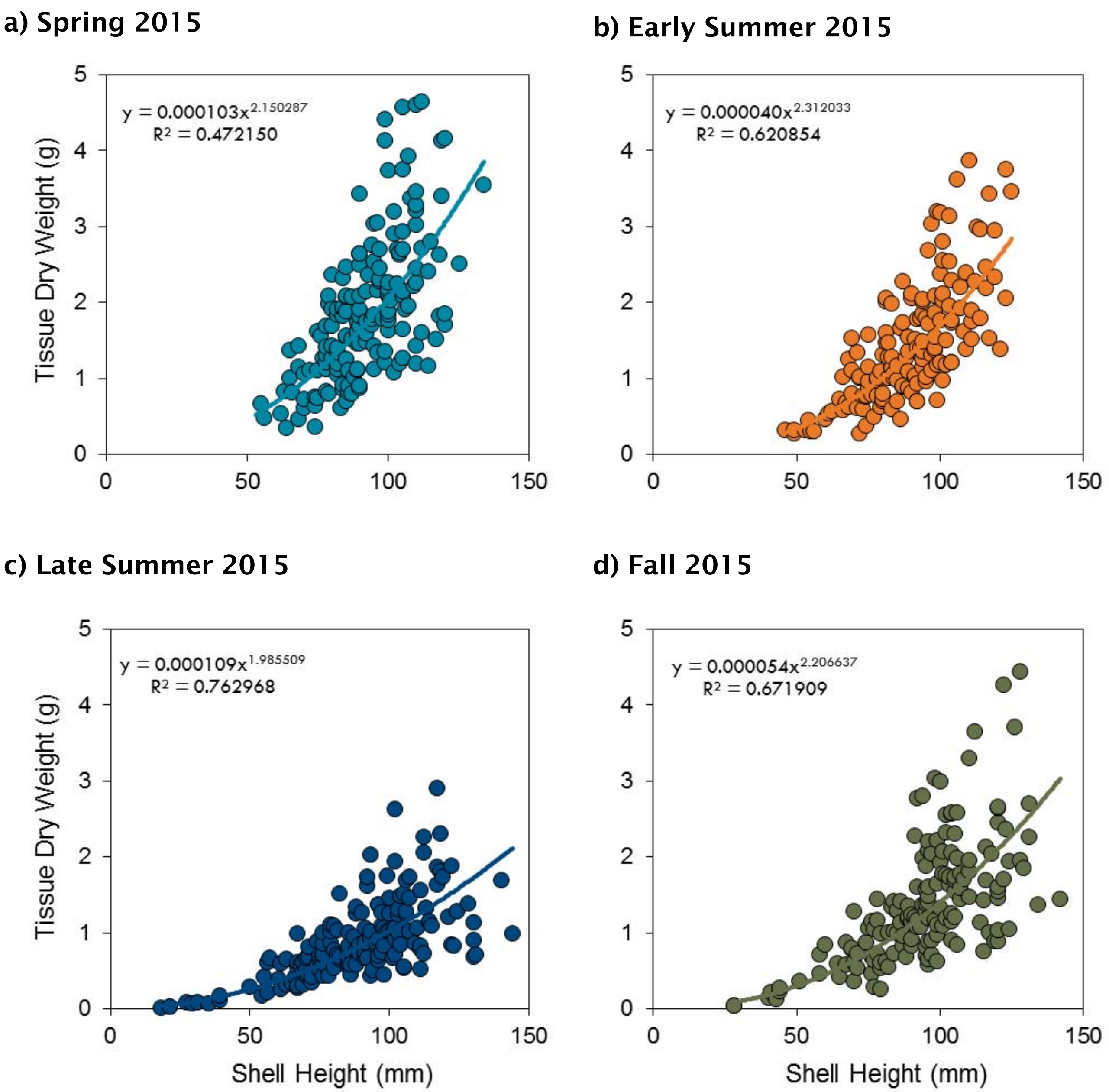

Fig. 5. Seasonal length to biomass regressions for oysters.

basket was found near its original location but had been disturbed sufficiently to empty it of its contents and, in some cases, flip it upside down.

Length to biomass relationships for both oysters and hooked mussels were best described as a power function and that varied with season. Although R^2-values (a measure of how well the equation fits the data) were often below the desired value of 0.80, this is not unexpected given the truncated range of size classes included in our

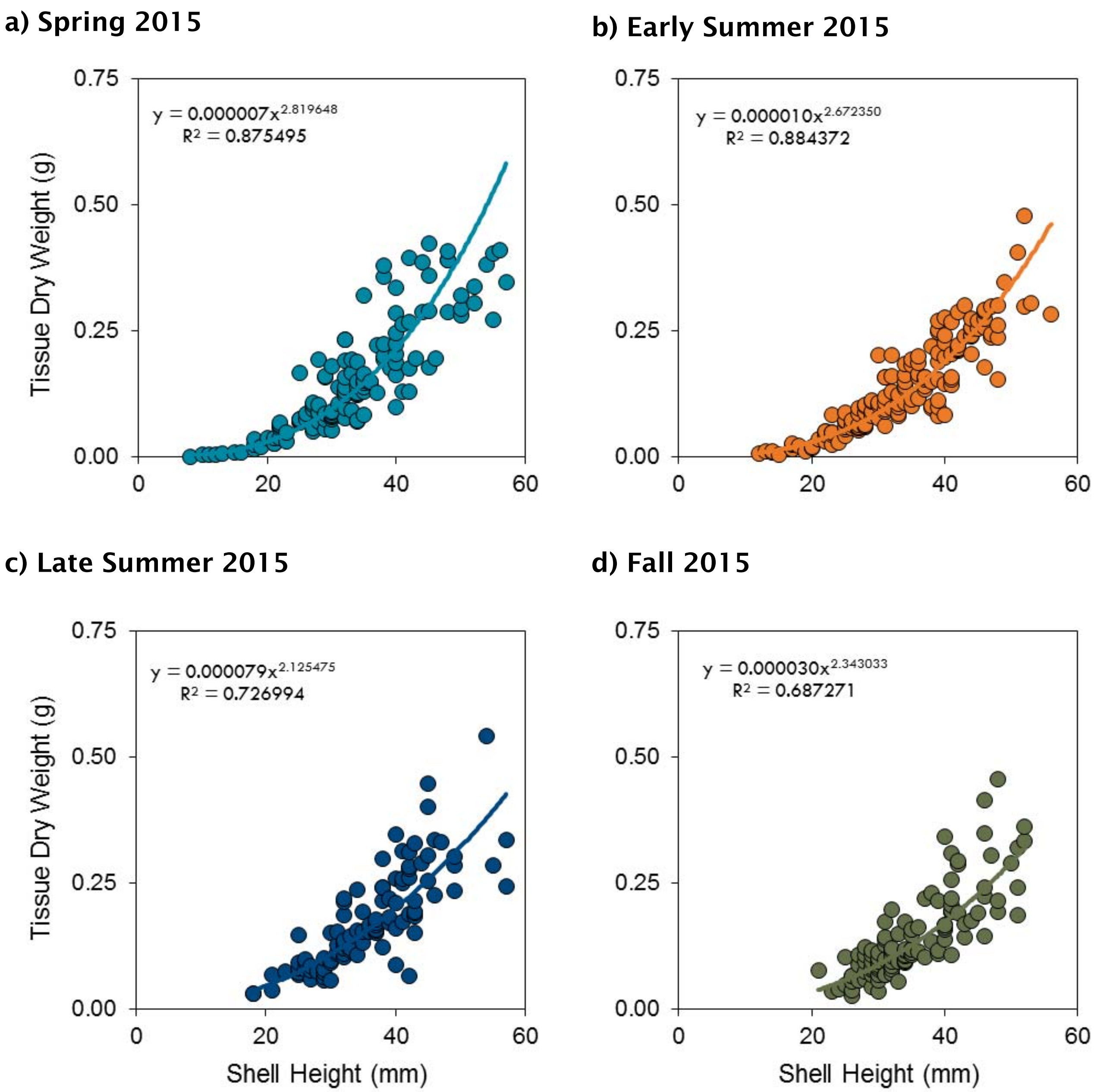

Fig. 6. Seasonal length to biomass regressions for the hooked mussel, *Ischadium recurvum.*

analyses. As expected, because hooked mussels are less variable in their morphology than oysters, the length to biomass regressions for mussels had higher R^2-values than those for oysters.

Positive relationships were identified for all three reef characteristics and the three major macrofaunal groups examined. In the majority of seasons, the relationship between both biomass and abundance of the hooked mussel, *Ischadium recurvum*, was a power function of oyster tissue biomass density, oyster abundance per square meter, and surface shell volume.

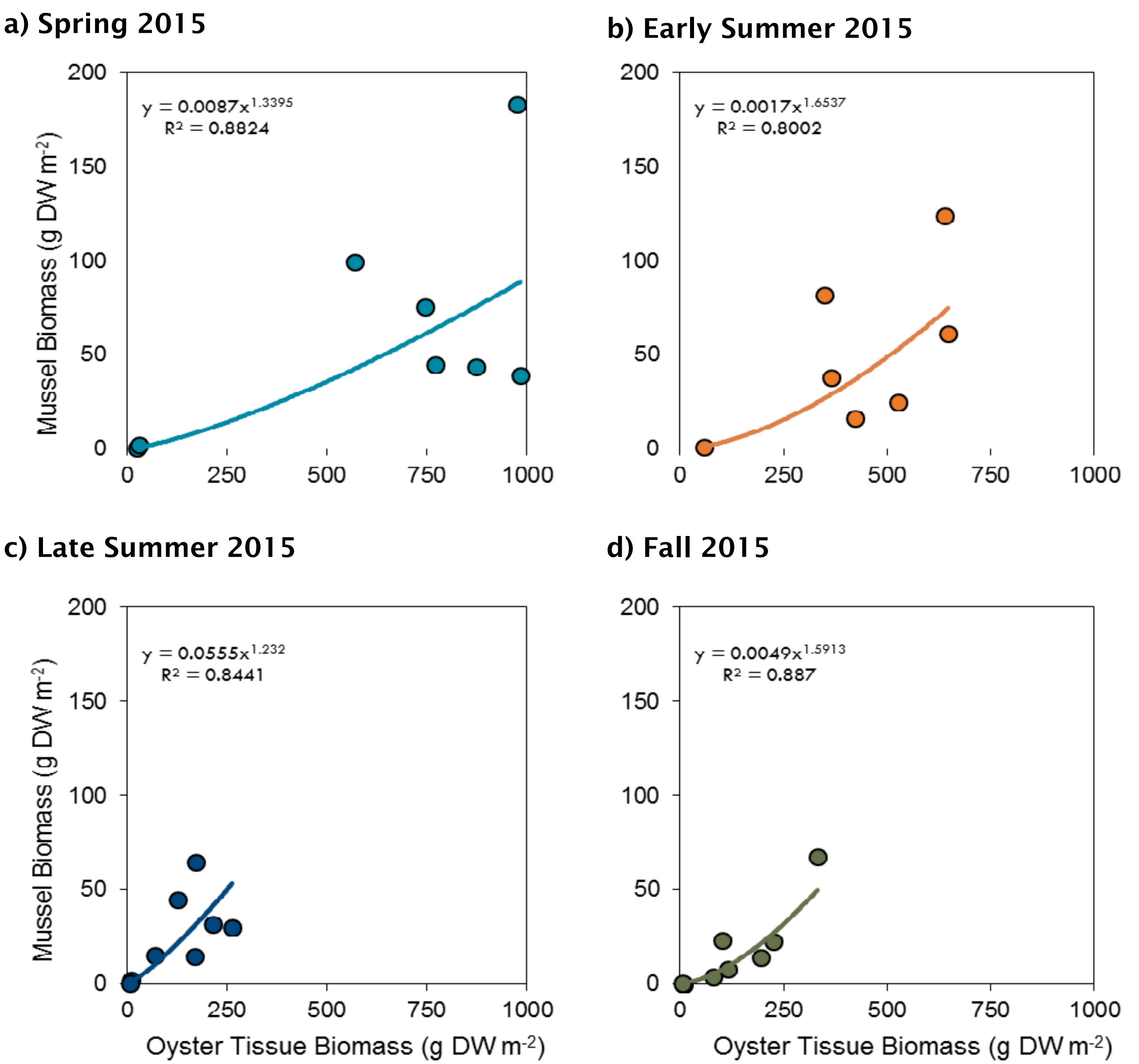

Fig. 7. Relationship between oyster tissue biomass and hooked mussel biomass.

Strongest relationships between oyster tissue biomass and mussel biomass were observed in spring and fall. The relationship between oyster tissue biomass and mussel abundance was found in the fall.

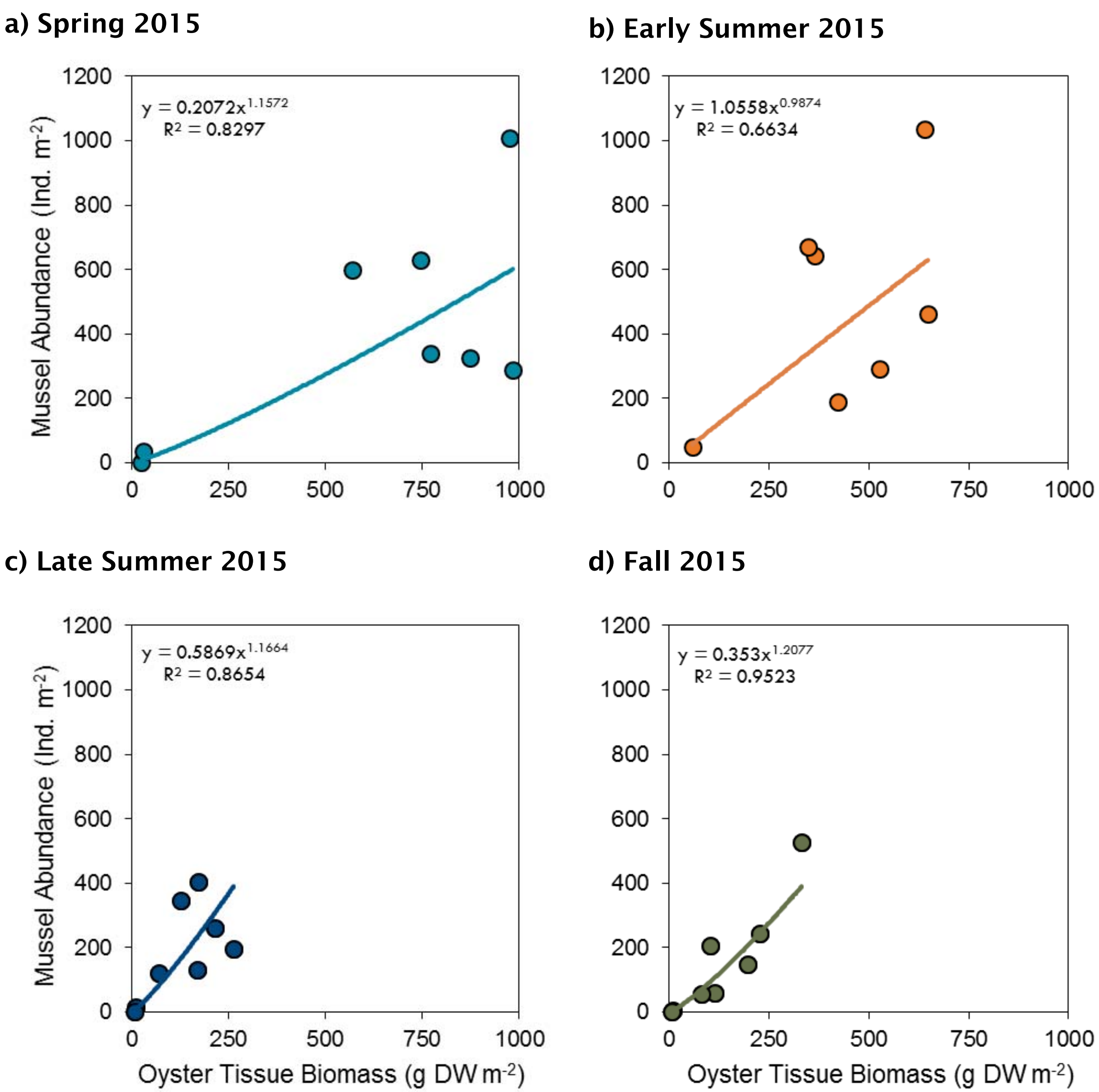

Fig. 8. Relationship between oyster tissue biomass and hooked mussel abundance.

The relationship between oyster abundance and mussel biomass was found in spring. Relationships were slightly more variable in the summer.

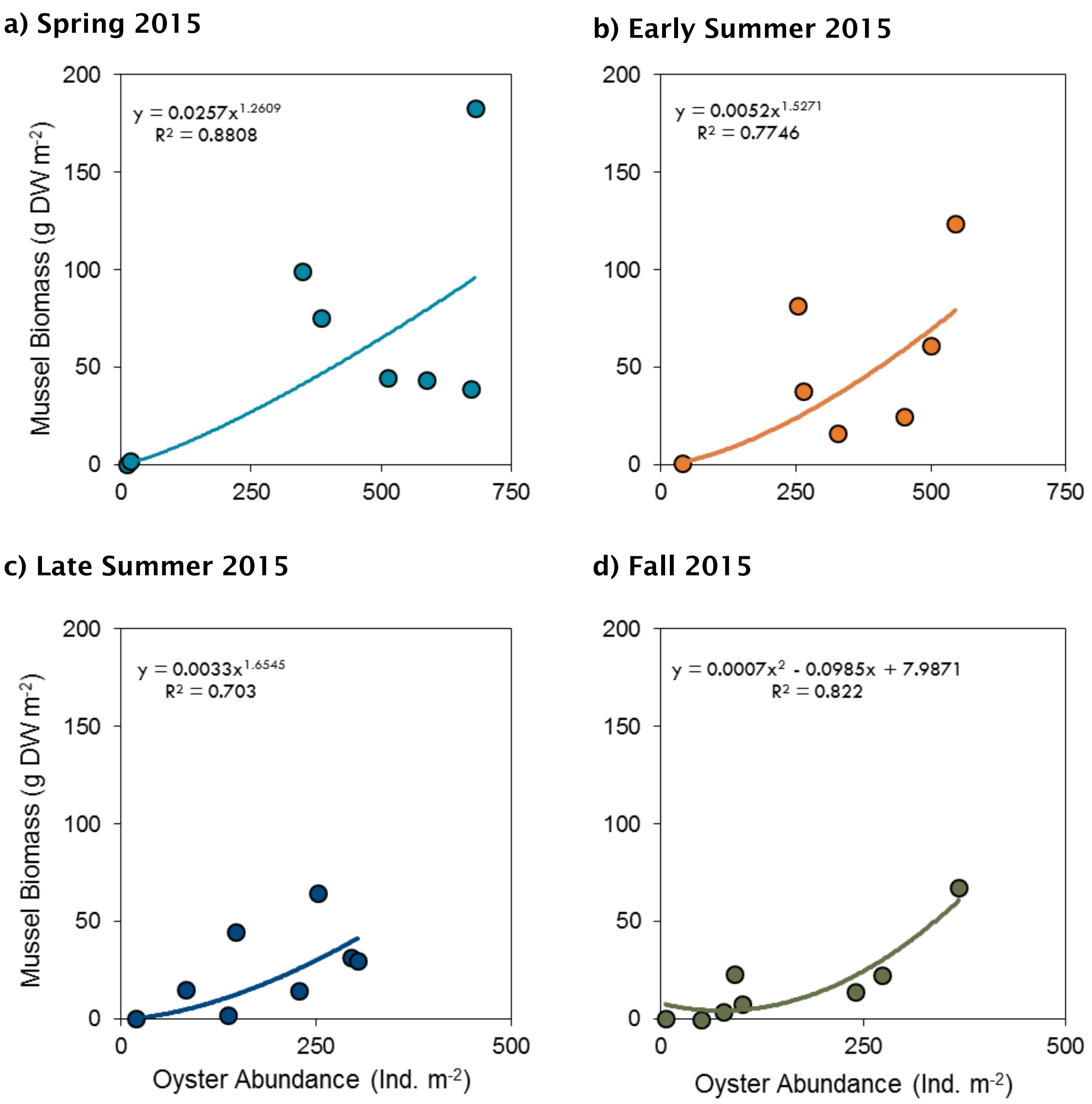

Fig. 9. Relationship between oyster abundance and hooked mussel biomass.

The relationships between oyster abundance and mussel abundance were relatively strong in spring and fall and weaker in the summer.

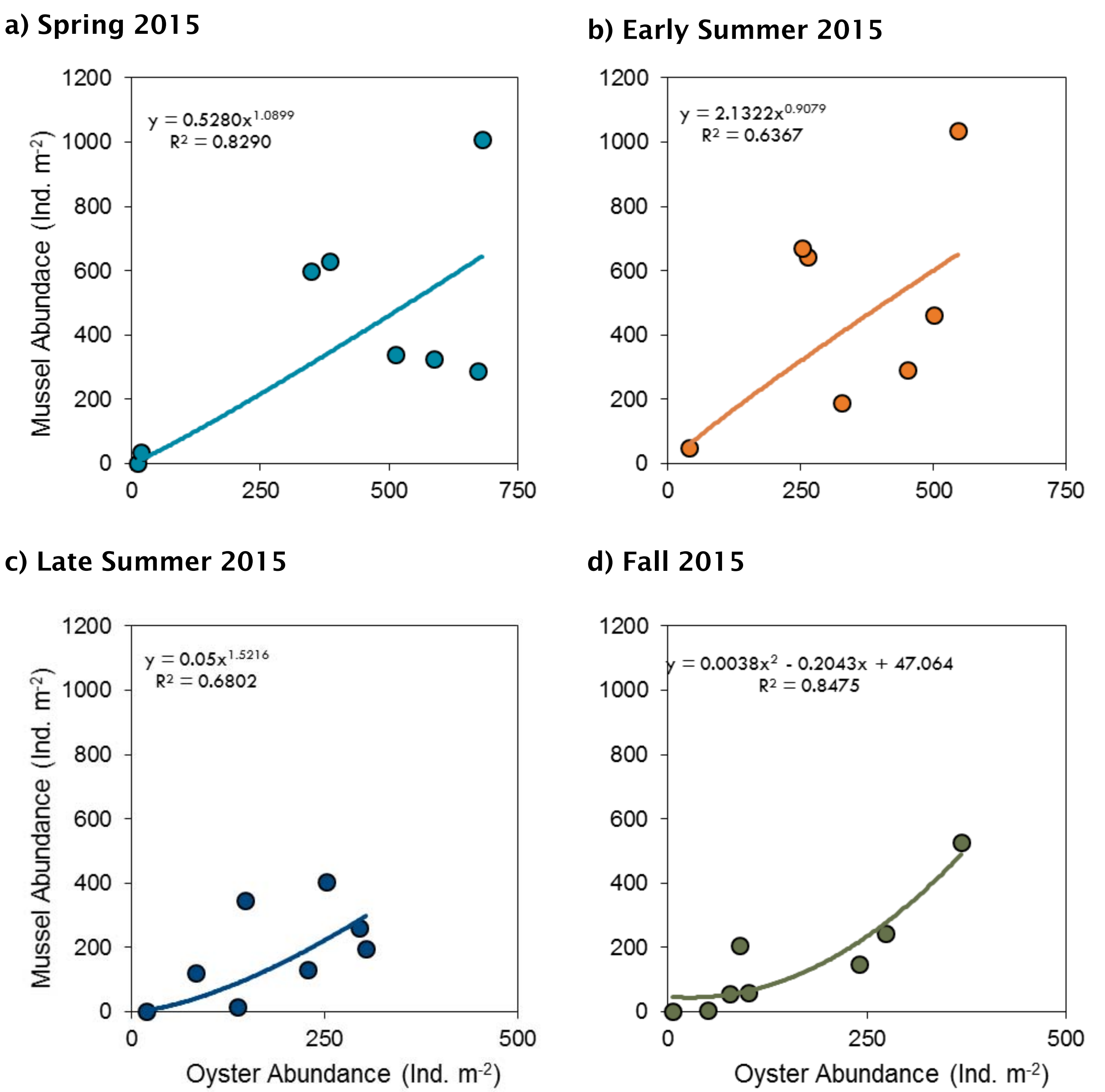

Fig. 10. Relationship between oyster abundance and hooked mussel abundance.

In contrast to oyster biomass and abundance, surface shell volume was a better predictor of mussel biomass in the summer than in the spring or fall.

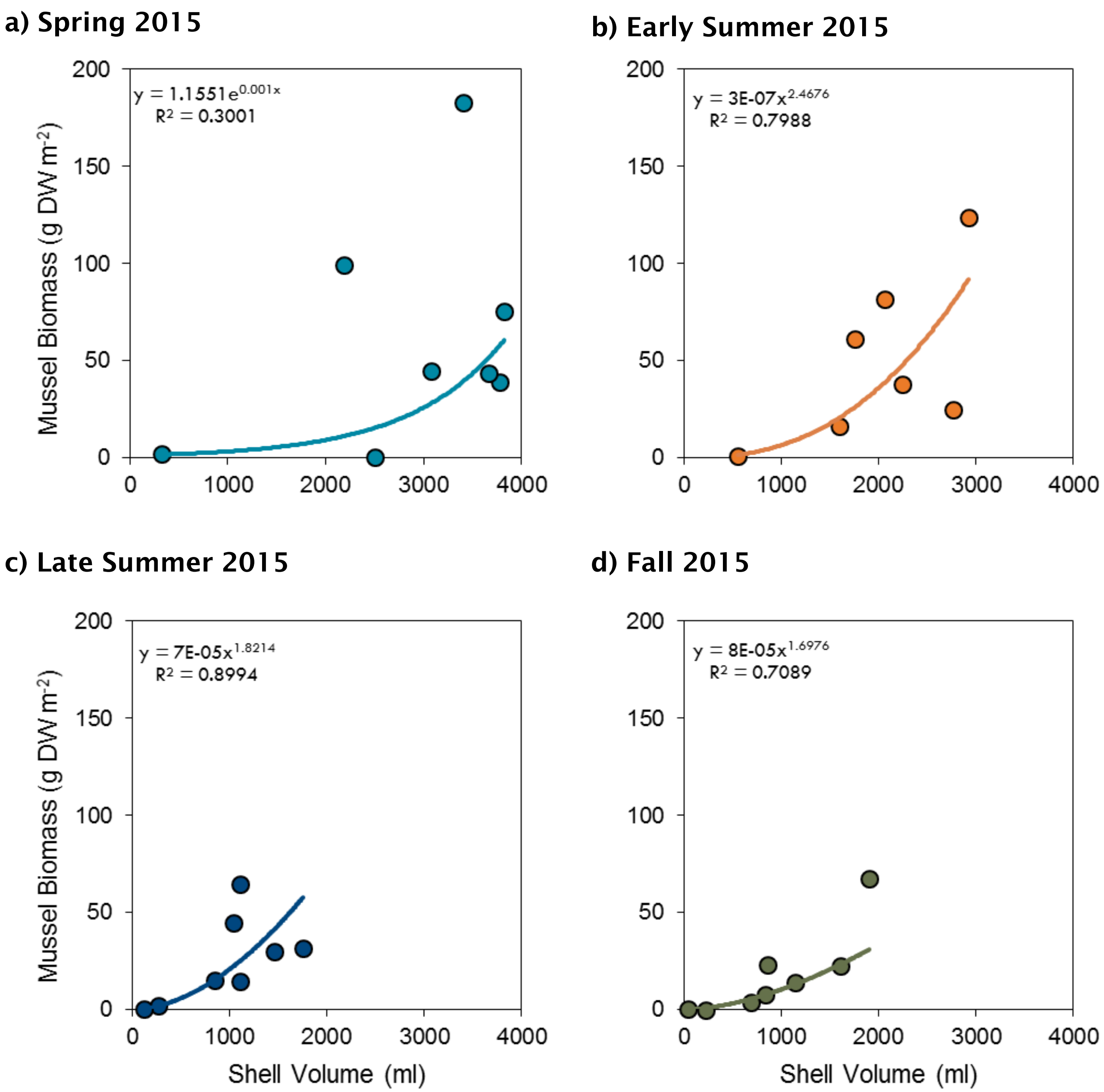

Fig. 11. Relationship between surface shell volume and hooked mussel biomass.

Strongest relationships between mussel abundance and shell volume were found in late summer and fall.

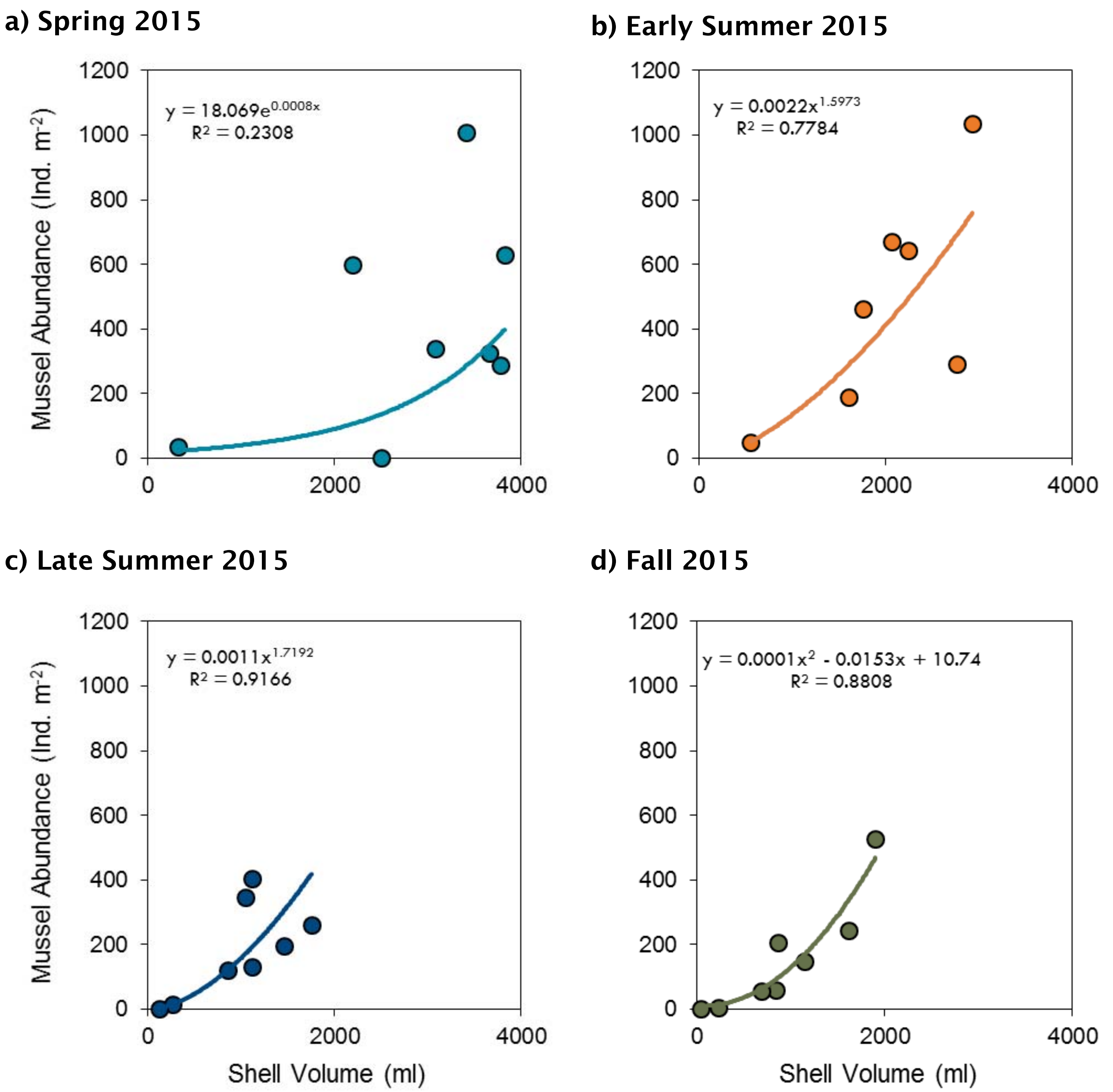

Fig. 12. Relationship between oyster shell volume and hooked mussel abundance.

In contrast to the patterns observed for the hooked mussel, the character of the relationships between the abundance and biomass of the mud crab, *Eurypanopeus depressus*, varied widely with season. While some relationships were best described by a power function, others were best described by linear, logarithmic or polynomial functions.

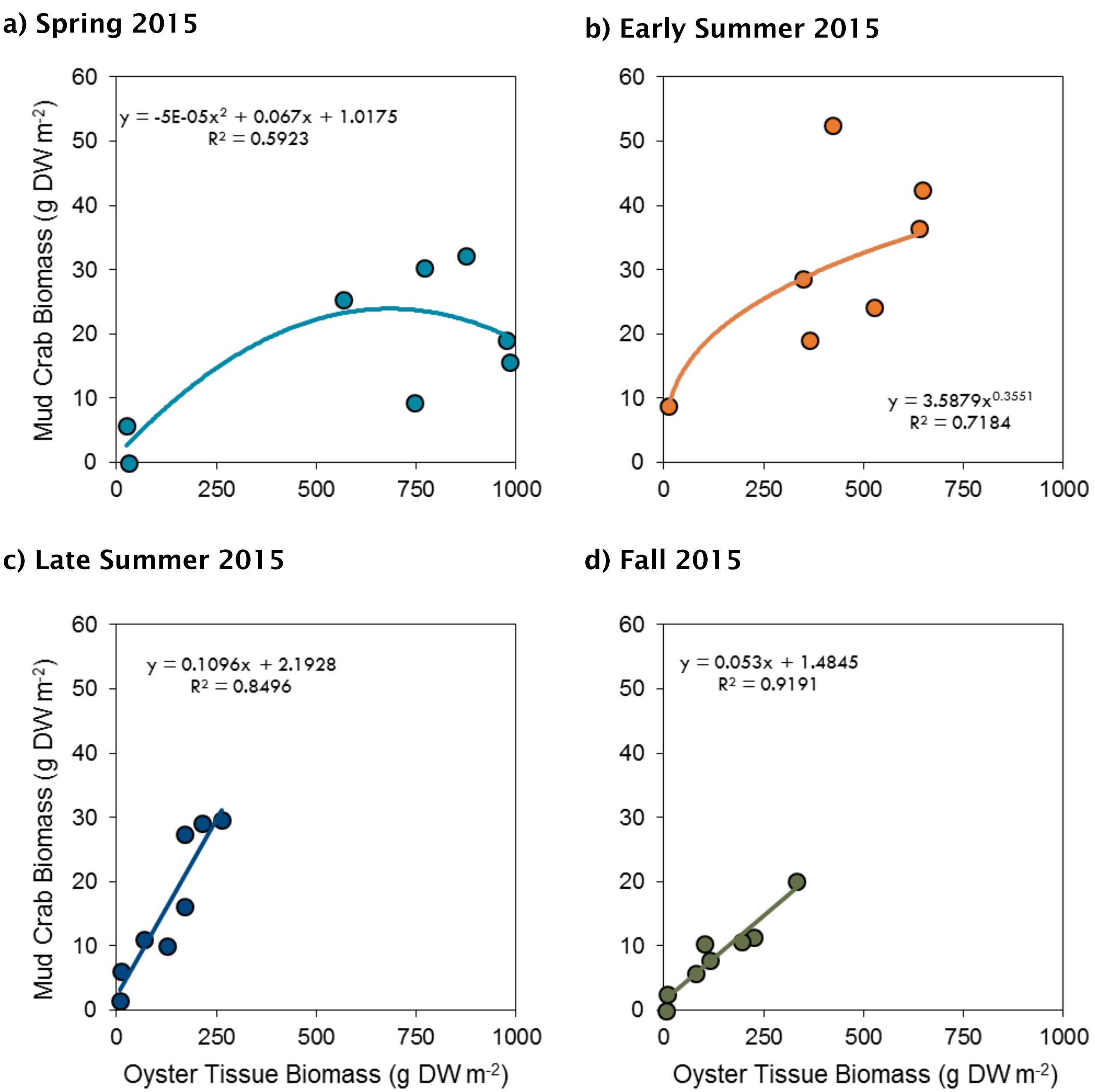

Fig. 13. Relationship between oyster tissue biomass and biomass of the mud crab, *Eurypanopeus depressus.*

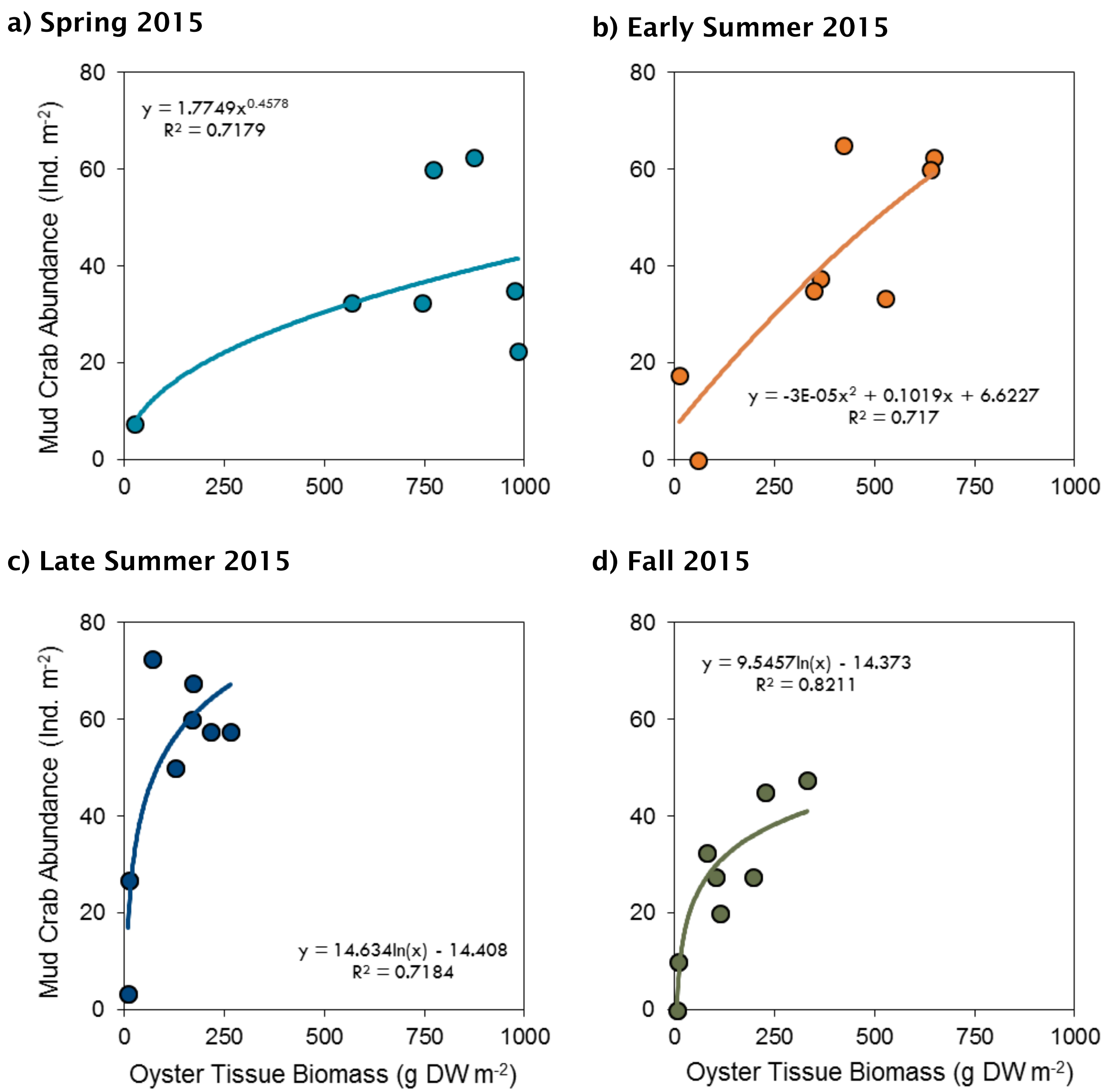

Fig. 14. Relationship between oyster tissue biomass and abundance of the mud crab, *Eurypanopeus depressus*.

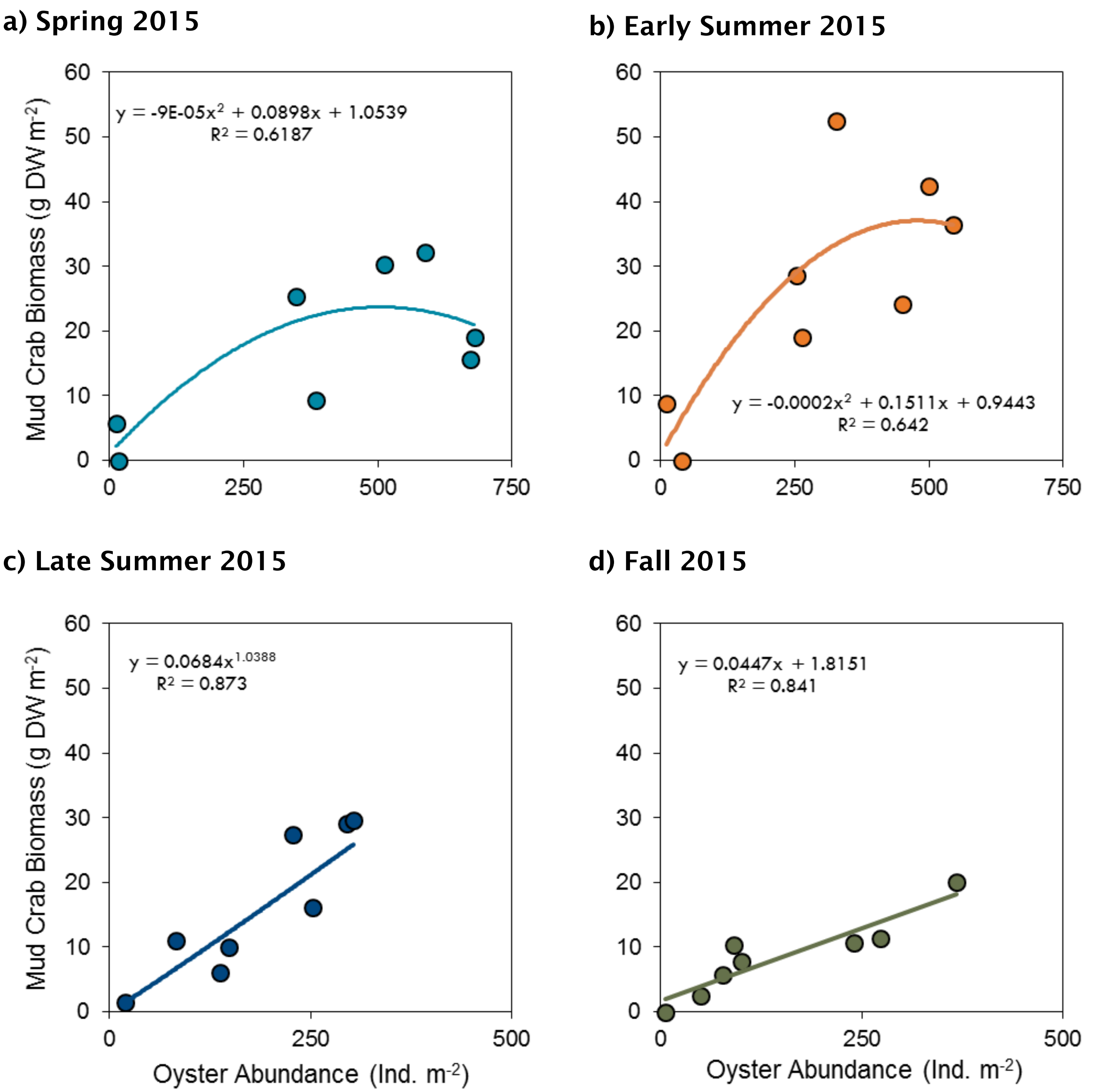

Fig. 15. Relationship between oyster abundance and biomass of the mud crab, *Eurypanopeus depressus.*

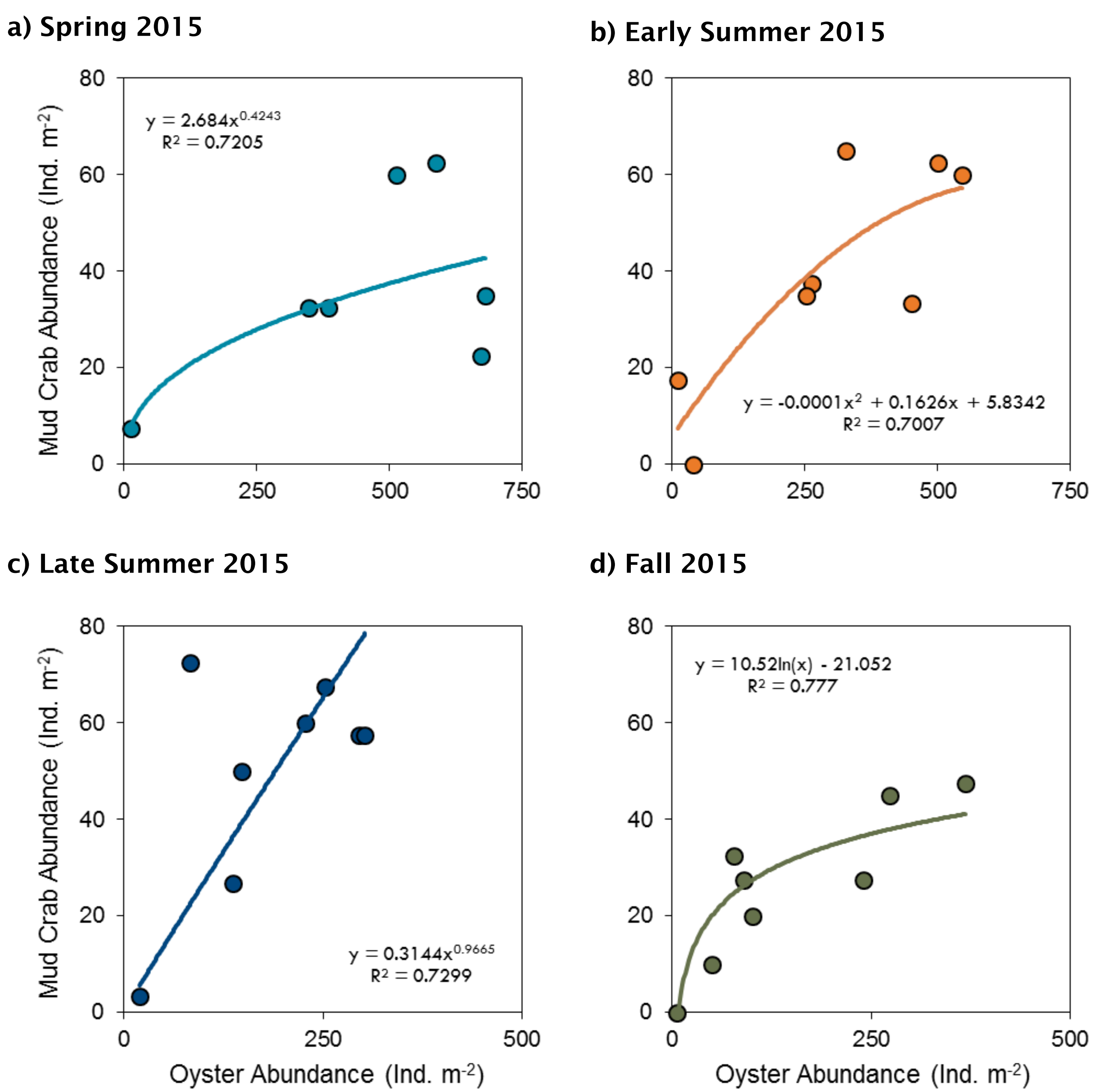

Fig. 16. Relationship between oyster abundance and abundance of the mud crab, *Eurypanopeus depressus.*

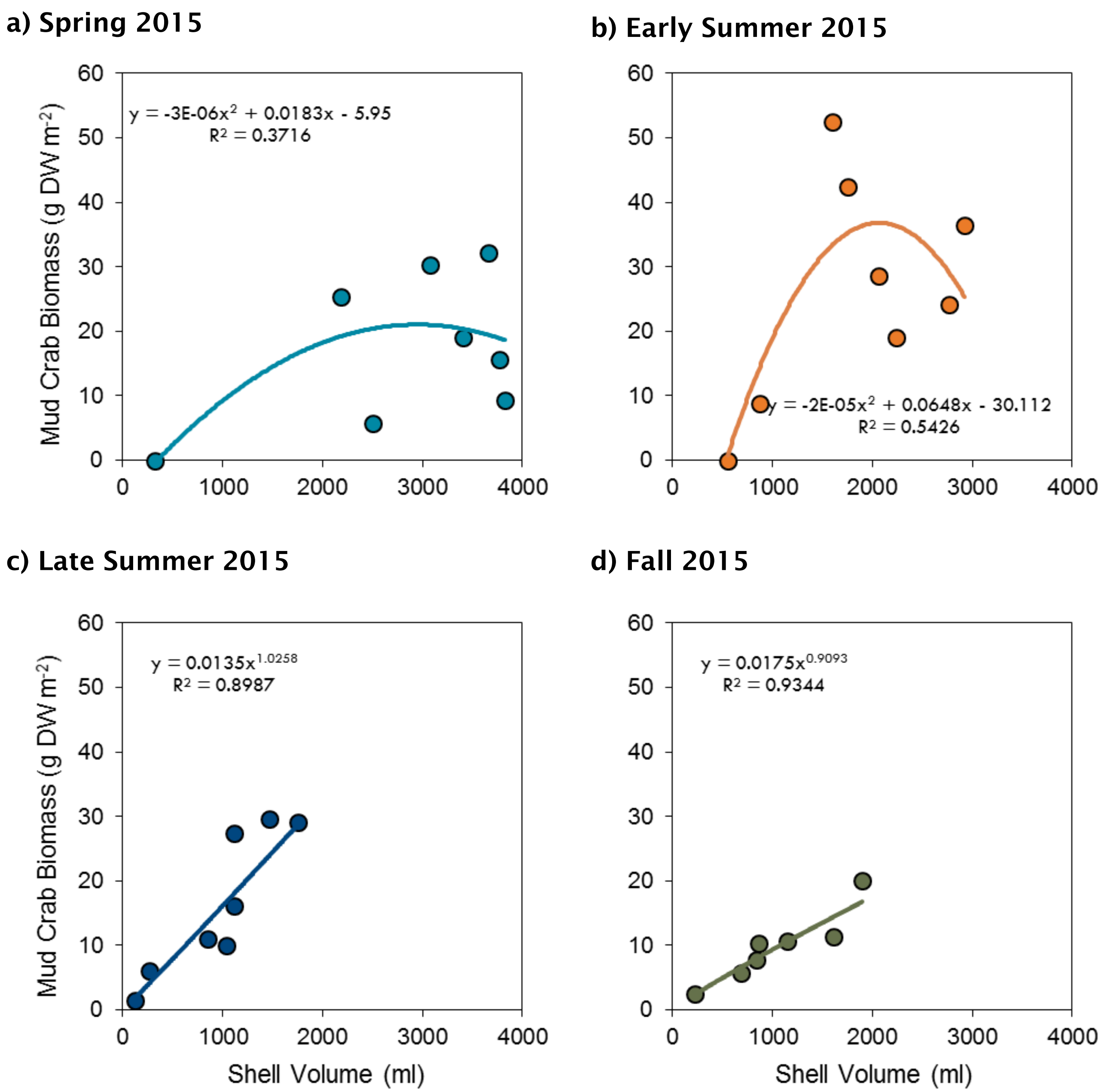

Fig. 17. Relationship between surface shell volume and biomass of the mud crab, *Eurypanopeus depressus.*

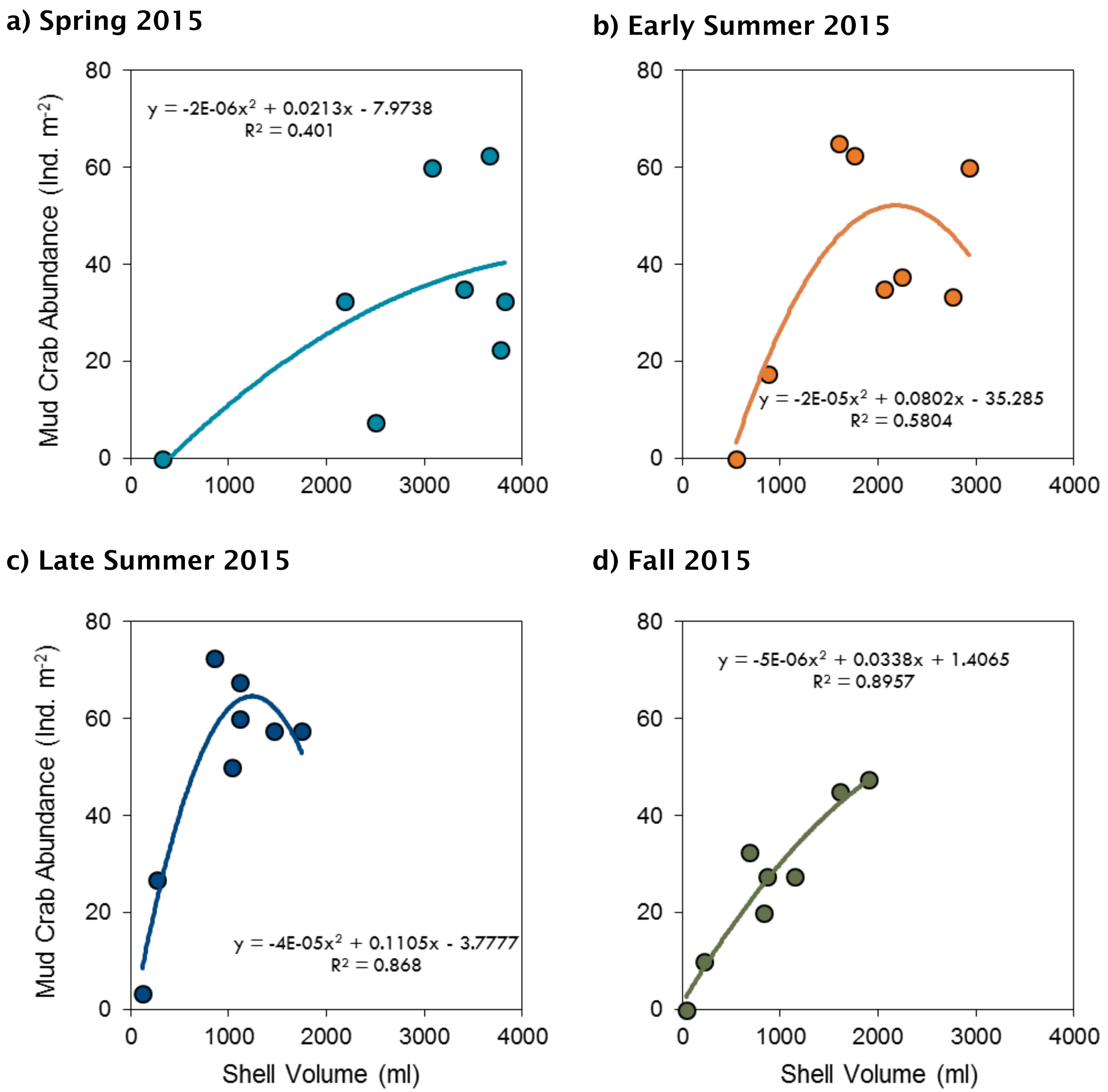

Fig. 18. Relationship between surface shell volume and abundance of the mud crab, *Eurypanopeus depressus.*

Like patterns observed for mud crabs, the character of the relationships between the abundance and biomass of the naked goby, *Gobiosoma bosc*, varied with season and reef metric. While some relationships were best described by a power function, others were best described by exponential or polynomial functions.

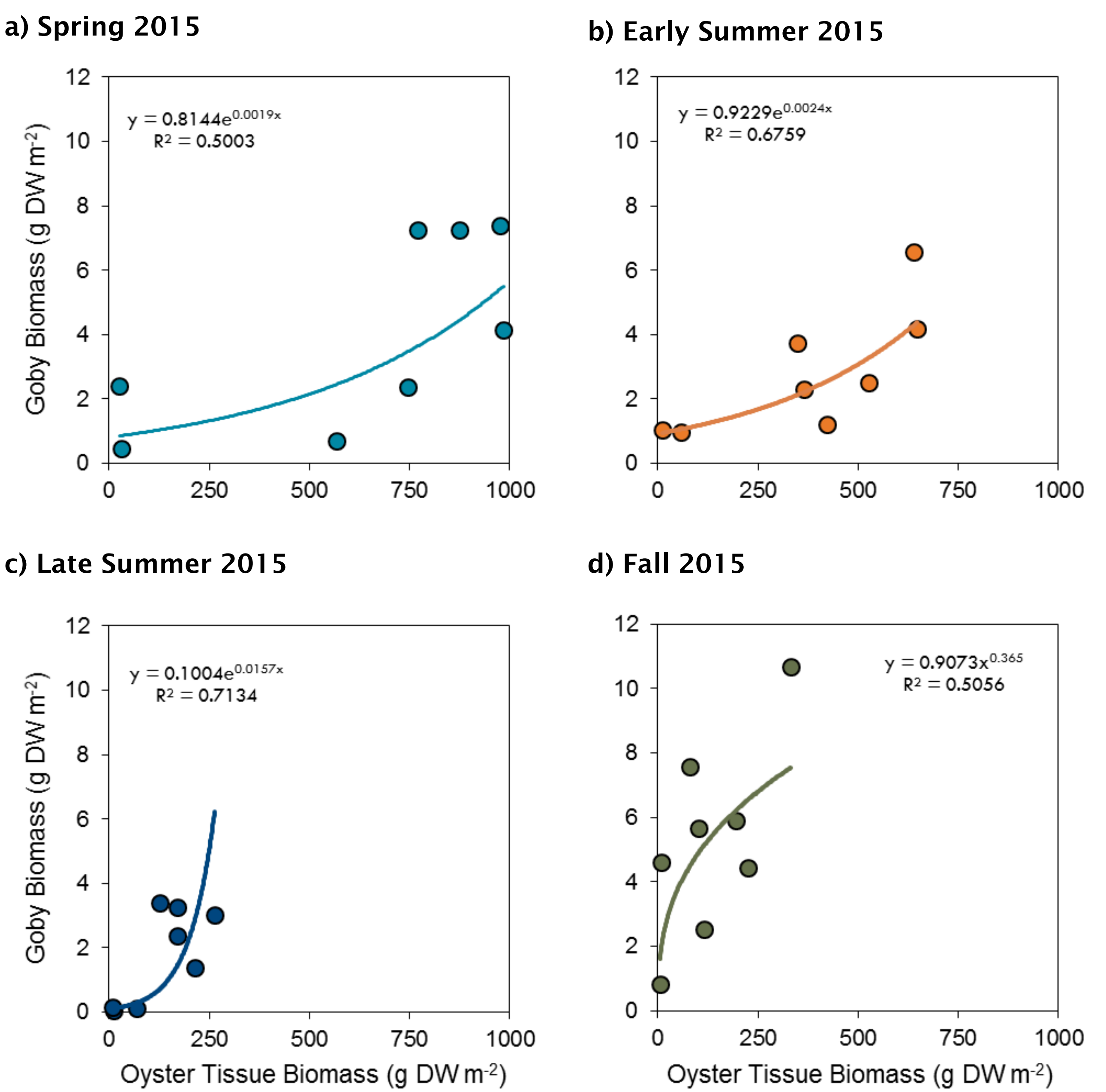

Fig. 19. Relationship between oyster tissue biomass and biomass of the naked goby, *Gobiosoma bosc.*

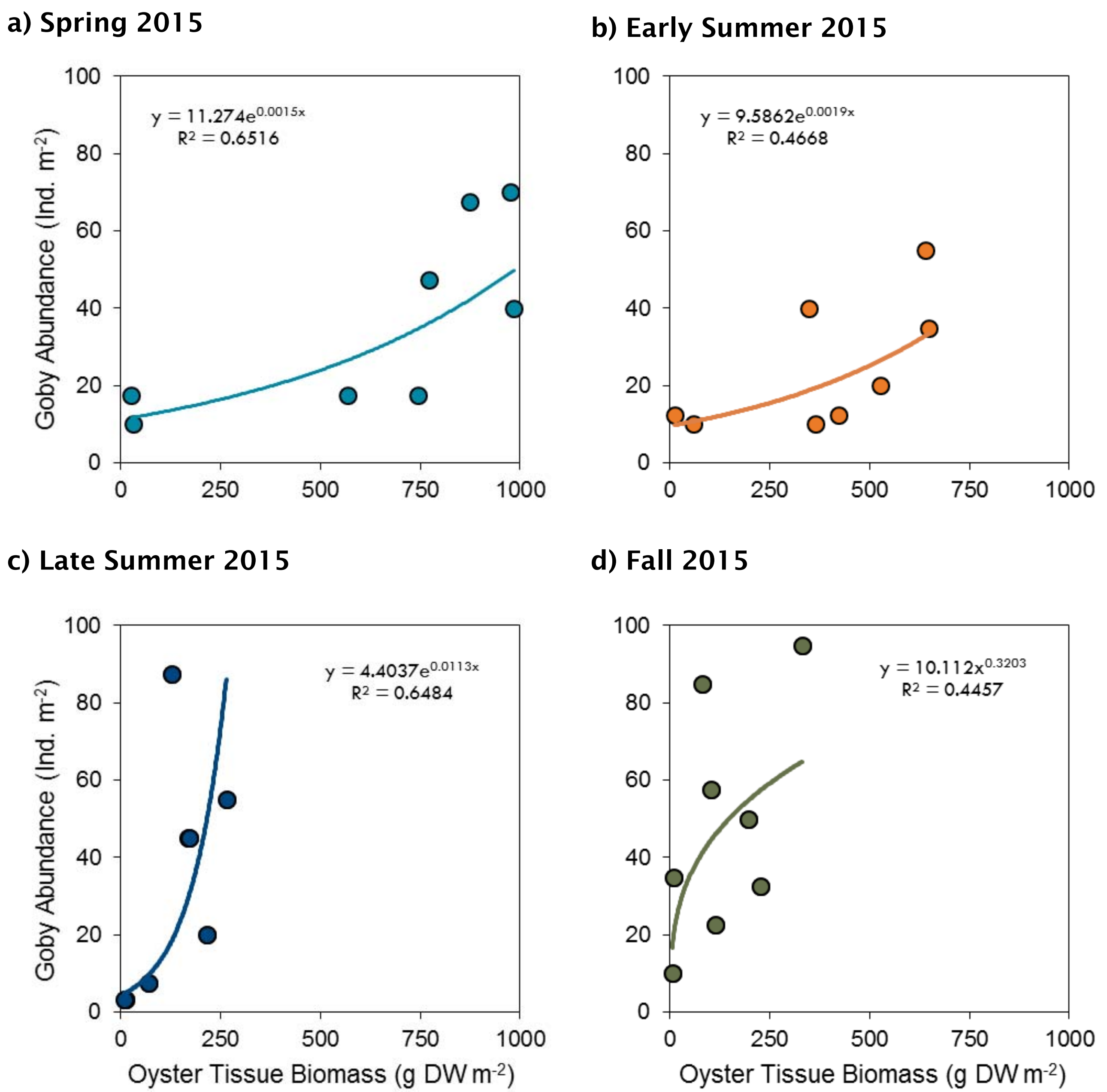

Fig. 20. Relationship between oyster tissue biomass and biomass of the naked goby, *Gobiosoma bosc.*

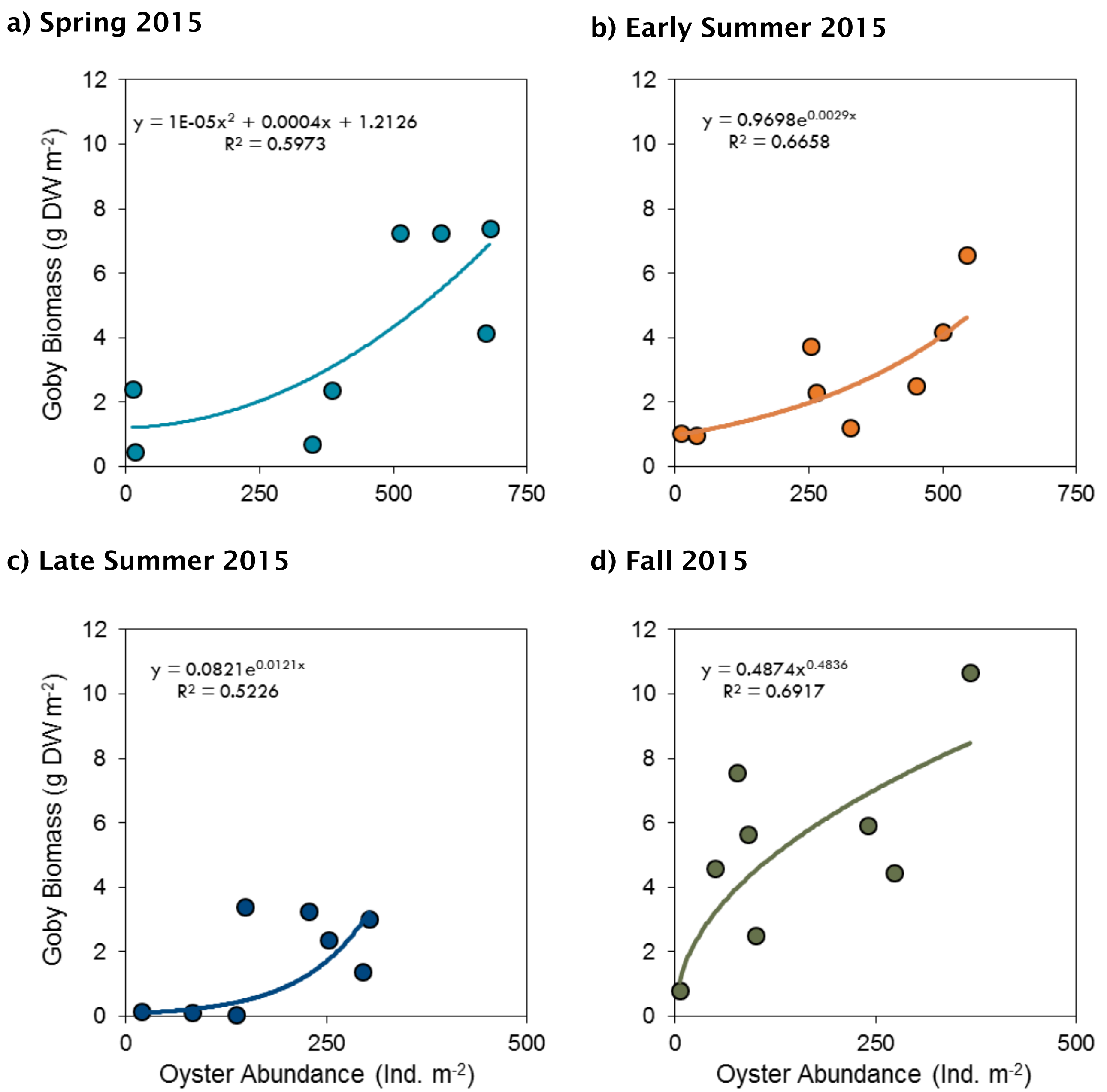

Fig. 21. Relationship between oyster abundance and biomass of the naked goby, *Gobiosoma bosc.*

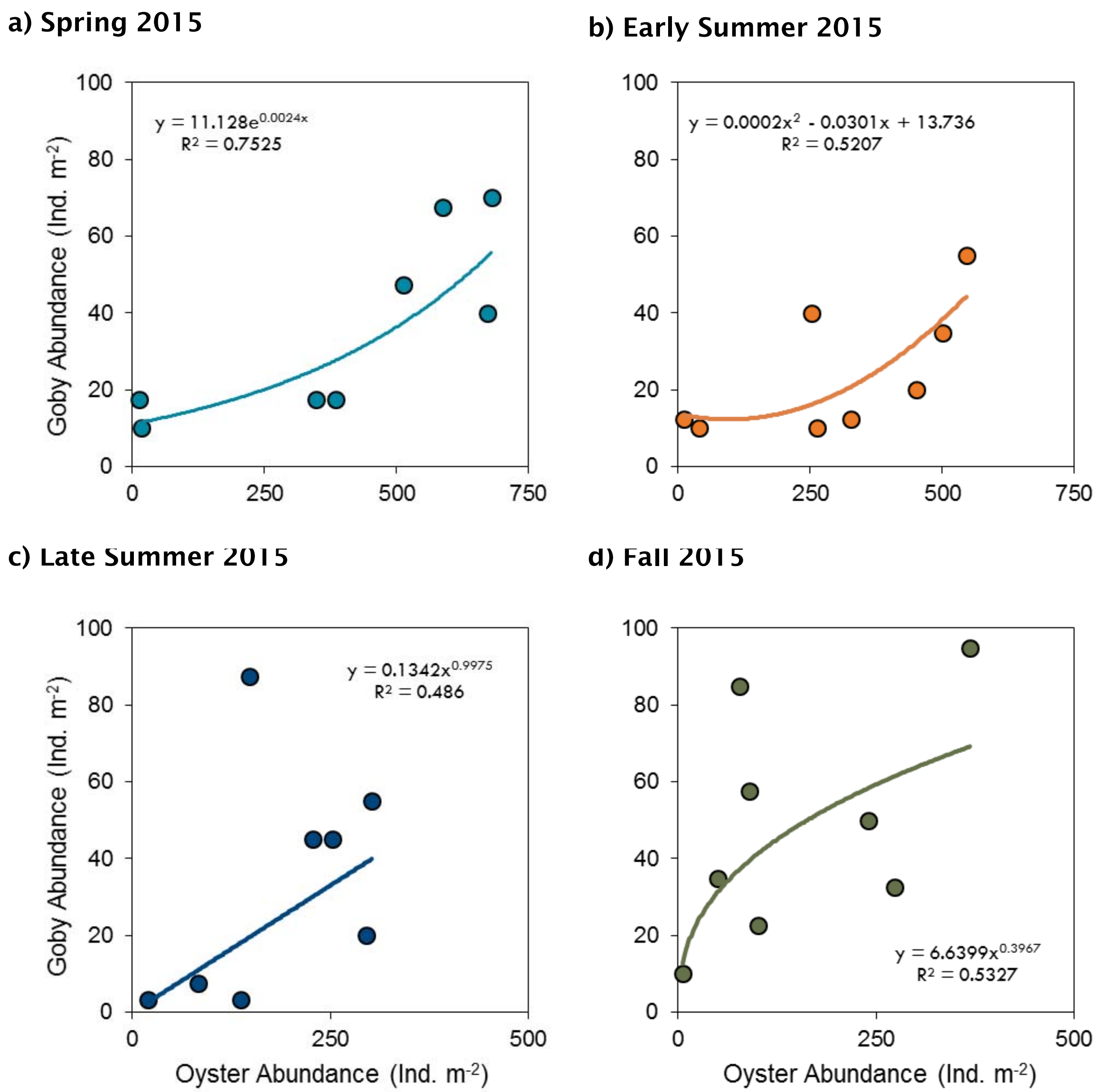

Fig. 22. Relationship between oyster abundance and biomass of the naked goby, *Gobiosoma bosc.*

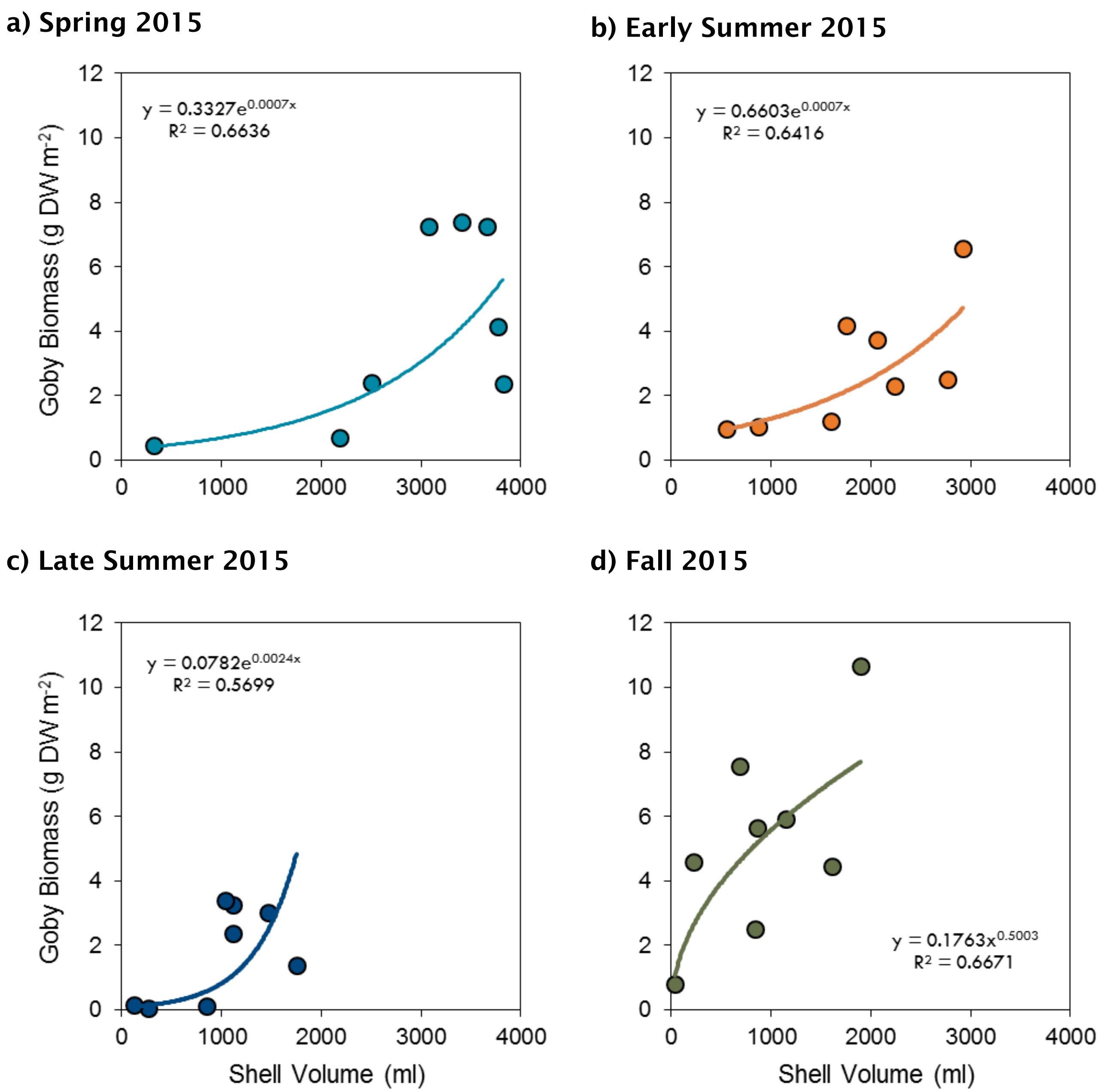

Fig. 23. Relationship between shell volume and biomass of the naked goby, *Gobiosoma bosc.*

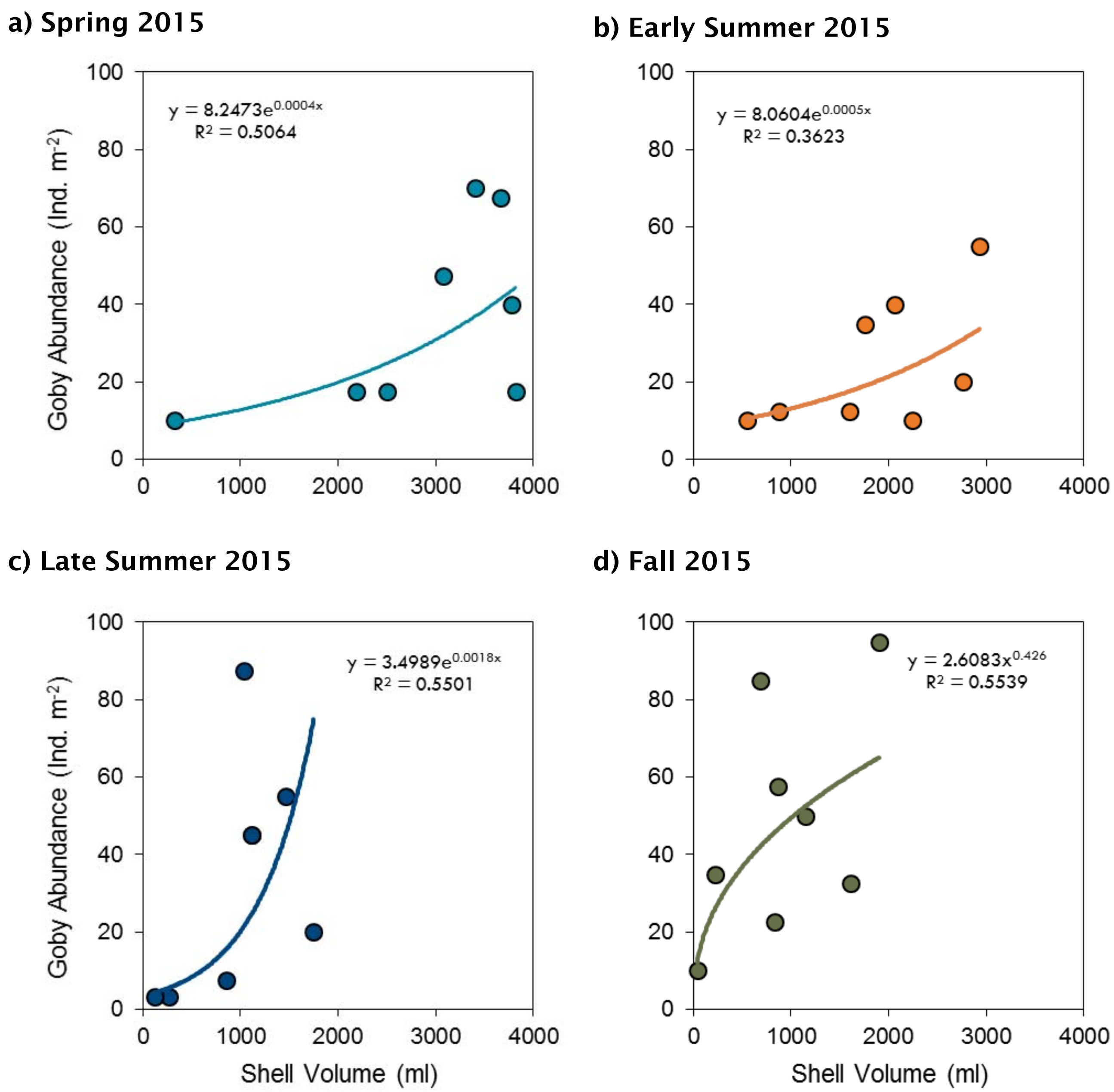

Fig. 24. Relationship between shell volume and abundance of the naked goby, *Gobiosoma bosc.*

Conclusions and recommendations

- Across a wide range of oyster biomass density, positive relationships exist between some components of the macrofaunal community and small-scale oyster biomass, oyster abundance and surface shell volume.
- Relationships between reef parameters and macrofauna species abundance and biomass vary by species and by season.
- Within species, the type of relationship between reef parameters and species abundance and biomass can be relatively consist as they were for mussels or vary fairly widely as they did for mud crabs and gobies.
- In many cases, simpler measures of reef characteristics such as oyster abundance and shell volume can provide predictions of macrofauna abundance and biomass that are reasonably comparable to more labor intensive measures such as oyster tissue biomass.

Literature Cited

Coen, LD, RD Brumbaugh, D Bushek, R Grizzle, MW Luckenbach, MH Posey, SP Powers, and SGTolley. 2007. Ecosystem services related to oyster restoration. Mar. Ecol. Prog. Ser. 341:303–307.

Coen, LD, DM Knott, EL Wenner, NH Hadley, AH Ringwood, and MY Bobo. 1999. Intertidal oyster reef studies in South Carolina: design, sampling, andexperimental focus for evaluating habitat value and function. Pages 133–156 in M. Luckenbach, W. R. Mann, and J. R. Wesson, editors. Oyster reef habitat restoration: a synopsis and synthesis of approaches. Virginia Institute of Marine Science Press, Gloucester Point, Virginia.

French McCay DP and JJ Rowe. 2003 Habitat restoration as mitigation for lost production at multiple trophic levels. Mar. Ecol. Prog. Ser. 264: 233−247.

Kellogg, ML, JC Cornwell, MS Owens, KT Paynter. 2013. Denitrification and nutrient assimilation on a restored oyster reef. Marine Ecology Progress Series 480: 1-19

Oyster Metrics Workgroup (OMW). 2011. Restoration goals, quantitative metrics and assessment protocols for evaluating success on restored oyster reef sanctuaries: A report submitted to the Sustainable Fisheries Goal Implementation Team of the Chesapeake Bay Program. 32p.

Rodney, WS and KT Paynter. 2006. Comparisons of macrofaunal assemblages on restored and nonrestored oyster reefs in mesohaline regions of Chesapeake Bay in Maryland. Journal of Exp. Mar. Bio. And Ecol. 335: 39-51.

Stunz, GW, TJ Minello and L Rozas. 2010. Relative value of oyster reef as habitat for estuarine nekton in Galveston Bay, TX. Mar. Ecol. Prog. Ser. 406: 147-159.

Wong, MC, CH Peterson and MF Piehler. 2011. Evaluating estuarine habitats using secondary production as a proxy for food web support. Mar Ecol. Prog. Ser. 440: 11–25.