Supplemental Information

Meta-Analysis of Nekton Utilization of Coastal Habitats in the Northern Gulf of Mexico

Journal name: Estuaries and Coasts

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Supplement 1: Tables and Figures

Tables

Table S1 ProQuest databases used for the keyword search and the author-based search.

#	Database
1	Aquatic Sciences and Fisheries Abstracts
2	Biosis Previews
3	Conference Papers Index
4	Ecology Abstracts
5	Ei Compendex
6	Environment Abstracts
7	Environmental Engineering Abstracts
8	Meteorological and Geoastrophysical Abstracts
9	National Technical Information Service (NTIS)
10	Oceanic Abstracts
11	ProQuest Dissertations and Theses
12	SciSearch

Table S2 Search terms used for the keyword search. The keyword search consisted of the following combination: Set 1 AND Set 2 AND Set 3 AND Set 4.

Set #	Search terms
Set 1	*Marsh? Or wetland? Or barrier island? Or oyster? Or SAV? Or seagrass? Or mangrove?*
Set 2	*Producti?*[a] *Or utiliz?*[b] *Or densit?*[c] *Or abundance? Or biomass? Or CPUE? Or weight? Or number?*
Set 3	*Louisiana? Or Gulf Coast? Or Gulf of Mexico? Or Texas? Or Alabama? Or Mississippi? Or Florida?*
Set 4	*Fish? Or nekton? Or macrofauna? Or crustacean? Or decapod?*

a. Includes words such as production, productivity, etc.

b. Includes words such as utilize, utilization, etc.

c. Includes words such as density, densities, etc.

Table S3 List of authors included in the author-based literature search. An asterisk (*) indicates authors who appeared four times or more in the keyword search. Authors without an asterisk appeared three times in the keyword search.

#	Authors	* Appeared 4 times or more
1	Baltz, D.M.	*
2	Boswell, K.M.	*
3	Caldwell, P.	*
4	Cowan Jr., J.H.	*
5	Heck Jr., K.L.	*
6	Holmquist, J.G.	*
7	Johnson, M.W.	*
8	La Peyre, M.	
9	Minello, T.J.	*
10	Nyman, J.A.	
11	Rakocinski, C.	*
12	Rooker, J.R.	*
13	Rozas, L.P.	*
14	Sheridan, P.	
15	Stunz, G.W.	*
16	Thayer, G.W.	*
17	Wilson, C.A.	*
18	Zimmerman, R.J.	*

Table S4 Habitat and season combinations used in the meta-analysis.

Analysis	Habitat type (and landscape)	Vegetation type	Season	# of combinations
1	Marsh (edge and interior) Oyster reef SAV Open-water NVB (near and far)	Saline	Spring Fall	8
2	Marsh (edge) Marsh (interior) Open-water NVB (near) Open-water NVB (far)	Saline	Spring Fall	8
3	Marsh (edge and interior)	Saline Brackish Intermediate	Spring Fall	6

Table S5 Fish and crustacean species included in the meta-analysis. Common names from the Integrated Taxonomic Information Systems (ITIS) database (http://www.itis.gov/).

Taxonomic group	Family	Scientific name	Common name
Crustaceans	Alpheidae	*Alpheus heterochaelis*	Bigclaw snapping shrimp
	Diogenidae	*Clibanarius vittatus*	Thinstripe hermit
	Menippidae	*Menippe adina*	Gulf stone crab
	Menippidae	*Menippe mercenaria*	Florida stone crab
	Ocypodidae	*Uca* spp.	Fiddler crab
	Palaemonidae	*Palaemonetes intermedius*	Brackish grass shrimp
	Palaemonidae	*Palaemonetes paludosus*	Eastern grass shrimp, riverine grass shrimp
	Palaemonidae	*Palaemonetes pugio*	Daggerblade grass shrimp
	Palaemonidae	*Palaemonetes vulgaris*	Common American prawn, common grass shrimp, marsh grass shrimp, marsh shrimp
	Panopeidae	*Dyspanopeus texanus*	Gulf grassflat crab
	Panopeidae	*Eurypanopeus depressus*	Flatback mud crab
	Panopeidae	*Eurypanopeus turgidus*	Ridgeback mud crab
	Panopeidae	*Panopeus herbstii*	Atlantic mud crab
	Panopeidae	*Rhithropanopeus harrisii*	Harris mud crab, estuarine mud crab
	Penaeidae	*Farfantepenaeus aztecus*	Brown shrimp, golden shrimp, northern brown shrimp, red shrimp, redtail shrimp
	Penaeidae	*Farfantepenaeus duorarum*	Bait shrimp, northern pink shrimp, pink shrimp, spotted shrimp
	Penaeidae	*Litopenaeus setiferus*	Northern white shrimp, white shrimp
	Porcellanidae	*Petrolisthes armatus*	Green porcelain crab
	Portunidae	*Callinectes sapidus*	Blue crab, bluepoint
	Sesarmidae	*Sesarma reticulatum*	Heavy marsh crab, purple marsh crab
	Xanthidae	Xanthidae spp.	Mud crabs, pebble crabs, rubble crabs
Fish	Ariidae	*Ariopsis felis*	Hardhead catfish
	Atherinopsidae	*Menidia beryllina*	Inland silverside, tidewater silverside
	Batrachoididae	*Opsanus beta*	Gulf toadfish
	Blenniidae	*Chasmodes bosquianus*	Striped blenny
	Clupeidae	*Brevoortia patronus*	Gulf menhaden, largescale menhaden
	Cynoglossidae	*Symphurus plagiusa*	Blackcheek tonguefish
	Cyprinodontidae	*Cyprinodon variegatus*	Sheepshead minnow, sheepshead pupfish
	Engraulidae	*Anchoa mitchilli*	Bay anchovy
	Fundulidae	*Adinia xenica*	Diamond killifish
	Fundulidae	*Fundulus grandis*	Gulf killifish
	Fundulidae	*Fundulus pulvereus*	Bayou killifish
	Fundulidae	*Lucania parva*	Rainwater killifish

Table S5 Fish and crustacean species included in the meta-analysis. Common names from the Integrated Taxonomic Information Systems (ITIS) database (http://www.itis.gov/).

Taxonomic group	Family	Scientific name	Common name
	Gobiesocidae	*Gobiesox strumosus*	Skilletfish
	Gobiidae	*Ctenogobius boleosoma*	Darter goby
	Gobiidae	*Gobiosoma bosc*	Naked goby
	Mugilidae	*Mugil cephalus*	Striped mullet, gray mullet, black mullet
	Ophichthidae	*Myrophis punctatus*	Speckled worm eel
	Paralichthyidae	*Paralichthys lethostigma*	Southern flounder
	Poeciliidae	*Gambusia affinis*	Mosquitofish, western mosquitofish
	Poeciliidae	*Poecilia latipinna*	Sailfin molly
	Sciaenidae	*Cynoscion arenarius*	Sand seatrout
	Sciaenidae	*Cynoscion nebulosus*	Spotted seatrout
	Sciaenidae	*Leiostomus xanthurus*	Spot
	Sciaenidae	*Micropogonias undulatus*	Atlantic croaker
	Sciaenidae	*Pogonias cromis*	Black drum
	Sciaenidae	*Sciaenops ocellatus*	Red drum
	Sparidae	*Archosargus probatocephalus*	Sheepshead
	Sparidae	*Lagodon rhomboides*	Pinfish
	Tetraodontidae	*Sphoeroides parvus*	Least puffer

Table S6 List of publications that passed the screening criteria. The table also indicates whether the publication was compiled in the database and included in the meta-analysis. Publications that contained data duplicated in another paper were not compiled in the database. Only studies that fit within the habitat-season combinations investigated were included in the meta-analysis.

#	Publications	Compiled in database?	Included in meta-analysis?
1	Allen, R.L., and D.M. Baltz. 1997. Distribution and microhabitat use by flatfishes in a Louisiana estuary. *Environmental Biology of Fishes* 50(1): 85–103.	Yes	No; data combined
2	Anton, A., J. Cebrian, C.M. Duarte, K.L. Heck Jr., and J. Goff. 2009. Low impact of Hurricane Katrina on seagrass community structure and functioning in the northern Gulf of Mexico. *Bulletin of Marine Science* 85(1): 45–59.	Yes	Yes
3	Armitage, A.R., C.-K. Ho, E.N. Madrid, M.T. Bell, and A. Quigg. 2014. The influence of habitat construction technique on the ecological characteristics of a restored brackish marsh. *Ecological Engineering* 62: 33–42.	Yes	No; does not fit habitat-season combinations
4	Baltz, D.M., and R.F. Jones. 2003. Temporal and spatial patterns of microhabitat use by fishes and decapod crustaceans in a Louisiana estuary. *Transactions of the American Fisheries Society* 132(4): 662–678.	Yes	No; data combined
5	Baltz, D.M., C. Rakocinski, and J.W. Fleeger. 1993. Microhabitat use by marsh-edge fishes in a Louisiana estuary. *Environmental Biology of Fishes* 36: 109–126.	Yes	No; data combined
6	Beck, S.L. 2012. The effects of oyster harvest on resident oyster reef communities and reef structure in coastal Louisiana. MS Thesis, Louisiana State University.	Yes	No; data combined
7	Bell, M.T. 2011. Aquatic macrophyte and animal communities in a recently restored brackish marsh: Possible influences of restoration design and the invasive plant species myriophyllum spicatum. MS Thesis, Texas A&M University.	Yes	No; does not fit habitat-season combinations
8	Birdsong, T.W. 2004. Complexity and nekton use of marsh edge habitats in Barataria Bay, Louisiana. MS Thesis, Louisiana State University.	No; duplicate data	N/A
9	Bologna, P.A.X., and K.L. Heck Jr. 1999. Macrofaunal associations with seagrass epiphytes: Relative importance of trophic and structural characteristics. *Journal of Experimental Marine Biology & Ecology* 242: 21–39.	Yes	No; does not fit habitat-season combinations
10	Boswell, K.M., M.P. Wilson, P.S.D. MacRae, C.A. Wilson, and J.H. Cowan Jr. 2010. Seasonal estimates of fish biomass and length distributions using acoustics and traditional nets to identify estuarine habitat preferences in Barataria Bay, Louisiana. *Marine and Coastal Fisheries: Dynamics, Management and Ecosystem Science* 2: 83–97.	Yes	No; data combined
11	Burfeind, D.D., and G.W. Stunz. 2006. The effects of boat propeller scarring intensity on nekton abundance in subtropical seagrass meadows. *Marine Biology* 148: 953–962.	Yes	Yes

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#	Publications	Compiled in database?	Included in meta-analysis?
12	Bush, C.S. 2003. Nekton utilization of restored habitat in a Louisiana marsh. MS Thesis, Louisiana State University.	Yes	No; data combined
13	Castellanos, D.L. 1997. Nekton use of submerged aquatic vegetation, marsh, and shallow unvegetated bottom in a Louisiana tidal freshwater ecosystem. MS Thesis, University of Southern Louisiana.	No; duplicate data	N/A
14	Castellanos, D.L., and L.P. Rozas. 2001. Nekton use of submerged aquatic vegetation, marsh, and shallow unvegetated bottom in the Atchafalaya River Delta, a Louisiana tidal freshwater ecosystem. *Estuaries* 24: 184–197.	Yes	No; does not fit habitat-season combinations
15	Caudill, M.C. 2005. Nekton Utilization of Black Mangrove (*Avicennia germinans*) and Smooth Cordgrass (*Spartina alterniflora*) Sites in Southwestern Caminada Bay, Louisiana. Baton Rouge, Louisiana: MS Thesis, Louisiana State University.	Yes	No; data combined
16	Cebrian, J., G.A. Miller, J.P. Stutes, A.L. Stutes, M.E. Miller, and K.L. Sheehan. 2009. A comparison of fish populations in shallow coastal lagoons with contrasting shoalgrass (*Halodule wrightii*) cover in the north central Gulf of Mexico. *Gulf and Caribbean Research* 21: 1–5.	Yes	Yes
17	Day, J.W., W.G. Smith, P.R. Wagner, and W.C. Stowe. 1973. Community structure and carbon budget of a salt marsh and shallow bay estuarine system in Louisiana. Publication No. LSU-SG-72-04. Prepared by the Center for Wetland Resources, Louisiana State University. May.	Yes	No; no density data
18	Duffy, K.C., and D.M. Baltz. 1998. Comparison of fish assemblages associated with native and exotic submerged macrophytes in the Lake Pontchartrain estuary, USA. *Journal of Experimental Marine Biology & Ecology* 223: 199–221.	Yes	No; data combined
19	Duque, G. 2004. Influence of the marsh edge on the structure and trophic ecology of the fish and macroinvertebrate community in a Louisiana Estuarine Ecosystem. PhD Dissertation, Louisiana State University.	Yes	No; data combined
20	Felley, J.D. 1987. Nekton assemblages of three tributaries to the Calcasieu Estuary, Louisiana. *Estuaries* 10(4): 321–329.	Yes	No; no density data
21	Fodrie, F.J., and K.L. Heck. 2011. Response of coastal fishes to the Gulf of Mexico oil disaster. *PLoS ONE* 6(7): e21609.	Yes	No; data combined
22	Gain, I. 2009. Oyster reefs as nekton habitat in estuarine ecosystems. MS Thesis, Texas A&M University.	Yes	Yes
23	Geary, B.W., J.R. Rooker, and J.W. Webb. 2001. Utilization of saltmarsh shorelines by newly settled sciaenids in a Texas estuary. *Gulf and Caribbean Research* 13: 37–50.	Yes	Yes

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24	Geraldi, N.R., S.P. Powers, K.L. Heck, and J. Cebrian. 2009. Can habitat restoration be redundant? Response of mobile fishes and crustaceans to oyster reef restoration in marsh tidal creeks. *Marine Ecology Progress Series* 389: 171–180.	Yes	No; data combined
25	Glancy, T.P., T.K. Frazer, C.E. Cichra, and W.J. Lingberg. 2003. Comparative patterns of occupancy by decapod crustaceans in seagrass, oyster, and marsh-edge habitats in a northeast Gulf of Mexico estuary. *Estuaries* 26(5): 1291–1301.	Yes	Yes
26	Gordon, J.A. 2010. Impacts of marsh loss and fragmentation on microhabitat use by estuarine nekton in Southwest Louisiana. MS Thesis, Louisiana State University.	Yes	No; does not fit habitat-season combinations
27	Gossman, B.P. 2005. Use of terraced marsh habitats by estuarine nekton in Southwestern Louisiana. MS Thesis, Louisiana State University.	No; duplicate data	N/A
28	Granados-Dieseldorff, P. 2006. Habitat use by nekton in a saltmarsh estuary along a stream-order gradient in Northeastern Barataria Bay, Louisiana. MS Thesis, Louisiana State University.	Yes	No; data combined
29	Gregalis, K.C., M.W. Johnson, and S.P. Powers. 2009. Restored oyster reef location and design affect responses of resident and transient fish, crab, and shellfish species in Mobile Bay, Alabama. *Transactions of the American Fisheries Society* 138: 314–327.	Yes	No; data combined
30	Herke, W.H., E.E. Knudsen, P.A. Knudsen, and B.D. Rogers. 1992. Effects of semi-impoundment of Louisiana marsh on fish and crustacean nursery use and export. *North American Journal of Fisheries Management* 12(1): 151–160.	Yes	No; no density data
31	Hitch, A.T., K.M. Purcell, S.B. Martin, P.L. Klerks, and P.L. Leberg. 2011. Interactions of salinity, marsh fragmentation and submerged aquatic vegetation on resident nekton assemblages of coastal marsh ponds. *Estuaries and Coasts* 34: 653–662.	Yes	No; data combined
32	Hoese, H.D. and R.S. Jones. 1963. Seasonality of larger animals in a Texas turtle grass community. In *Publications of the Institute of Marine Science of the University of Texas*, Volume 9, 37–47. Port Aransas, TX.	Yes	Yes
33	Homer, M. 1975. Seasonal abundance, biomass, diversity, and trophic structure of fish in a saltmarsh tidal creek affected by a coastal power plant. Augusta, Georgia: ERDA 2nd Thermal Ecol Symp.	Yes	Yes
34	Humphries, A.T. 2010. Effects of habitat structural complexity on nekton assemblages: Lab and field observations in Southern Louisiana. MS Thesis, Louisiana State University.	No; duplicate data	N/A

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35	Humphries, A.T., M.K. La Peyre, M.E. Kimball, and L.P. Rozas. 2011. Testing the effect of habitat structure and complexity on nekton assemblages using experimental oyster reefs. *Journal of Experimental Marine Biology & Ecology* 409(1–2): 172–179.	Yes	Yes
36	Jones, R.F., D.M. Baltz, and R.L. Allen. 2002. Patterns of resource use by fishes and macroinvertebrates in Barataria Bay, Louisiana. *Marine Ecology Progress Series* 237: 271–289.	Yes	No; data combined
37	Kang, S.-R. 2011. Aquatic macroinvertebrate and nekton community structure in a chenier marsh ecosystem: Implications for Whooping Crane prey availability. PhD Dissertation, Louisiana State University.	No; duplicate data	N/A
38	Kang, S.-R., and S.L. King. 2013. Effects of hydrologic connectivity and environmental variables on nekton assemblage in a coastal marsh system. *Wetlands* 33: 321–334.	Yes	No; data combined
39	Kanouse, S., M.K. La Peyre, and J.A. Nyman. 2006. Nekton use of Ruppia maritima and non-vegetated bottom habitat types within brackish marsh ponds. *Marine Ecology Progress Series* 327: 61–69.	No; duplicate data	N/A
40	Kanouse, S.C. 2003. Nekton use and growth in three brackish marsh pond microhabitats. MS Thesis, Louisiana State University.	Yes	No; data combined
41	Kelley Jr., J.R. 1965. A taxonomic survey of the fishes of Delta National Wildlife Refuge with emphasis upon distribution and abundance. MS Thesis, Louisiana State University.	Yes	No; no density data
42	Kimball, M.E., L.P. Rozas, K.M. Boswell, and J.H. Cowan Jr. 2010. Evaluating the effect of slot size and environmental variables on the passage of estuarine nekton through a water control structure. *Journal of Experimental Marine Biology & Ecology* 395: 181–190.	Yes	No; no density data
43	King, S.P., and P. Sheridan. 2006. Nekton of new seagrass habitats colonizing a subsided salt marsh in Galveston Bay, Texas. *Estuaries* 29(2): 286–296.	Yes	Yes
44	Kurz, R.C., R.W. Fenwick, and K.A. Davis. 1998. A comparison of fish communities in restores and natural salt marshes in Tampa Bay, Florida. In *Proceedings of the Twenty Fourth Annual Conference on Ecosystems Restoration and Creation*, ed. P.J. Cannizzaro, 38–51. May 1997.	Yes	No; data combined
45	La Peyre, M.K., and T.W. Birdsong. 2008. Physical variation of non-vegetated marsh edge habitats, and use patterns by nekton in Barataria Bay, Louisiana, USA. *Marine Ecology Progress Series* 356: 51–61.	Yes	Yes
46	La Peyre, M.K., and J. Gordon. 2012. Nekton density patterns and hurricane recovery in submerged aquatic vegetation, and along non-vegetated natural and created edge habitats. *Estuarine, Coastal and Shelf Science* 98: 108–118.	Yes	No; does not fit habitat-season combinations

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47	La Peyre, M.K., B. Gossman, and J.A. Nyman. 2007. Assessing functional equivalency of nekton habitat in enhanced habitats: Comparison of terraced and unterraced marsh ponds. *Estuaries and Coasts* 30(3): 526–536.	Yes	No; data combined
48	La Peyre, M.K., L. Schwarting, and S. Miller. 2013. Baseline data for evaluating the development trajectory and provision of ecosystem services by created fringing oyster reefs in Vermilion Bay, Louisiana. U.S. Geological Survey Open-File Report 2013-1053.	Yes	No; does not fit habitat-season combinations
49	La Peyre, M.K., L. Schwarting, and S. Miller. 2013. Preliminary assessment of bioengineered fringing shoreline reefs in Grand Isle and Breton Sound, Louisiana. U.S. Geological Survey Open-File Report 2013-1040.	Yes	No; data combined
50	La Peyre, M.K., A.T. Humphries, S.M. Casas, and J.F. La Peyre. 2014. Temporal variation in development of ecosystem services from oyster reef restoration. *Ecological Engineering* 63: 34–44.	Yes	No; data combined
51	Llewellyn, C., and M. La Peyre. 2011. Evaluating ecological equivalence of created marshes: Comparing structural indicators with stable isotope indicators of blue crab trophic support. *Estuaries and Coasts* 34: 172–184.	Yes	No; does not fit habitat-season combinations
52	MacRae, P.S.D. 2006. A Community approach to identifying essential fish habitat of spotted seatrout, *Cynoscion nebulosus*, in Barataria Bay, LA. PhD Dissertation, Louisiana State University.	Yes	No; no density data
53	Maiaro, J.L. 2007. Disturbance effects on nekton communities of seagrass and bare substrates in Biloxi Marsh, Louisiana. MS Thesis, Louisiana State University.	Yes	No; does not fit habitat-season combinations
54	Merino, J.H., L.P. Rozas, T.J. Minello, and P.F. Sheridan. 2010. Effects of marsh terracing on nekton abundance at two locations in Galveston Bay, Texas. *Wetlands* 30: 693–704.	Yes	Yes
55	Minello, T.J. 1999. Nekton densities in shallow estuarine habitats of Texas and Louisiana and the identification of essential fish habitat. *American Fisheries Society Symposium* 22: 43–75.	Yes	No; data combined
56	Minello, T.J. 2000. Temporal development of salt marsh value for nekton and epifauna: Utilization of dredged material marshes in Galveston Bay, Texas, USA. *Wetlands Ecology and Management* 8: 327–341.	Yes	No; data combined
57	Minello, T.J., and L.P. Rozas. 2002. Nekton in Gulf Coast wetlands: Fine-scale distributions, landscape patterns, and restoration implications. *Ecological Applications* 12(2): 441–455.	Yes	Yes
58	Minello, T.J., and J.W. Webb. 1997. Use of natural and created Spartina alterniflora salt marshes by fishery species and other aquatic fauna in Galveston Bay, Texas, USA. *Marine Ecology Progress Series* 151: 165–179.	Yes	Yes

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59	Minello, T.J., and R.J. Zimmerman. 1992. Utilization of natural and transplanted Texas salt marshes by fish and decapod crustaceans. *Marine Ecology Progress Series* 90: 273–285.	Yes	Yes
60	Minello, T.J., G.A. Matthews, and P.A. Caldwell. 2008. Population and production estimates for decapod crustaceans in wetlands of Galveston Bay, Texas. *Transactions of the American Fisheries Society* 137: 129–146.	Yes	Yes
61	Minello, T.J., R.J. Zimmerman, and R. Medina. 1994. The importance of edge for natant macrofauna in a created salt marsh. *Wetlands* 14(3): 184–198.	Yes	Yes
62	Minello, T.J., J.W. Webb Jr., R.J. Zimmerman, R.B. Wooten, J.L. Martinez, T.J. Baumer, and M.C. Pattillo. 1991. Habitat availability and utilization by benthos and nekton in Hall's Lake and West Galveston Bay. NOAA Technical Memorandum NMFS-SEFC-275.	Yes	Yes
63	Nevins, J.A., J.B. Pollack, and G.W. Stunz. 2014. Characterizing nekton use of the largest unfished oyster reef in the United States compared with adjacent estuarine habitats. *Journal of Shellfish Research* 33(1): 227–238.	Yes	No; data combined
64	O'Connell, J.L., and J.A. Nyman. 2010. Marsh terraces in coastal Louisiana increase marsh edge and densities of waterbirds. *Wetlands* 30: 125–135.	Yes	No; data combined
65	Peterson, G.W., and R.E. Turner. 1994. The value of salt marsh edge vs interior as a habitat for fish and decapod crustaceans in a Louisiana tidal marsh. *Estuaries* 17(18): 235–262.	Yes	No; no density data
66	Peterson, M.S., and A.G. Stricklin. 2008. Restoration and faunal composition of patchy, small intertidal *Crassostrea virginica* oyster reefs within the Grand Bay National Estuarine Research Reserve, North-Central Gulf of Mexico. Mobile, Alabama: Fisheries Ecology Laboratory, University of Southern Mississippi. Prepared for The Nature Conservancy, Alabama Coastal Program.	Yes	Yes
67	Peterson, M.S., C.F. Rakocinski, and B.H. Comyns. 2000. Nekton densities in the Pascagoula River Estuary: Anthropogenic effects on essential fish habitat. Final Technical Report. Mississippi-Alabama Sea Grant Consortium. September 15.	Yes	No; does not fit habitat-season combinations
68	Piazza, B.P. 2009. The role of climate variability and riverine pulsing in the community dynamics of estuarine nekton in Breton Sound, Louisiana. PhD Dissertation, Louisiana State University.	Yes	Yes
69	Piazza, B.P., and M.K. La Peyre. 2007. Restoration of the annual flood pulse in Breton Sound, Louisiana, USA: Habitat change and nekton community response. *Aquatic Biology* 1: 109–119.	No; duplicate data	N/A

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70	Piazza, B.P., and M.K. La Peyre. 2009. The effect of Hurricane Katrina on nekton communities in the tidal freshwater marshes of Breton Sound, Louisiana, USA. *Estuarine, Coastal and Shelf Science* 83(1): 97–104.	Yes	Yes
71	Plunket, J., and M.K. La Peyre. 2005. Oyster beds as fish and macroinvertebrate habitat in Barataria Bay, Louisiana. *Bulletin of Marine Science* 77(1): 155–164.	Yes	No; data combined
72	Plunket, J.T. 2003. A comparison of finfish assemblages on subtidal oyster shell (Cultched Oyster Lease) and mud bottom in Barataria Bay, Louisiana. MS Thesis, Louisiana State University.	No; duplicate data	N/A
73	Poulakis, G.R., D.A. Blewett, and M.E. Mitchell. 2003. The effects of season and proximity to fringing mangroves on seagrass-associated fish communities in Charlotte Harbor, Florida. *Gulf of Mexico Science* 21(2): 171–184.	Yes	No; data combined
74	Rakocinski, C.F., D.M. Baltz, and J.W. Fleeger. 1992. Correspondence between environmental gradients and the community structure of marsh-edge fishes in a Louisiana estuary. *Marine Ecology Progress Series* 80: 135–148.	Yes	No; data combined
75	Reed, D.J., M.S. Peterson, and B.J. Lezina. 2006. Reducing the effects of dredged material levees on coastal marsh function: Sediment deposition and nekton utilization. *Environmental Management* 37(5): 671–685.	Yes	Yes
76	Reed, D.J., A. Beall, L. Martinez, T.J. Minello, A.M.U. O'Conell, L.P. Rozas, S. Penland, R.C. Cashner, and A.M. Commagere. 2007. Modeling relationships between the abundance of fishery species, coastal wetland, landscapes, and salinity in the Barataria Basin, Louisiana. Prepared for NOAA, NMFS and the Louisiana Coastal Wetlands Conservation and Restoration Task Force. December.	Yes	Yes
77	Reese, M.M., G.W. Stunz, and A.M. Bushon. 2008. Recruitment of estuarine-dependent nekton through a new tidal inlet: The opening of Packery Channel in Corpus Christi, TX, USA. *Estuaries and Coasts* 31: 1143–1157.	Yes	Yes
78	Robillard, M.M.R., G.W. Stunz, and J. Simons. 2010. Relative value of deep subtidal oyster reefs to other estuarine habitat types using a novel sampling method. *Journal of Shellfish Research* 29(2): 291–302.	Yes	No; data combined
79	Rooker, J.R., S.A. Holt, M.A. Soto, and G.J. Holt. 1998. Postsettlement patterns of habitat use by sciaenid fishes in subtropical seagrass meadows. *Estuaries* 21(2): 318–327.	Yes	No; season not specified
80	Roth, A.-M.F. 2009. Anthropogenic and natural perturbations on Lower Barataria Bay, Louisiana: Detecting responses of marsh-edge fishes and decapod crustaceans. PhD Dissertation, Louisiana State University.	Yes	Yes

Table S6 List of publications that passed the screening criteria. The table also indicates whether the publication was compiled in the database and included in the meta-analysis. Publications that contained data duplicated in another paper were not compiled in the database. Only studies that fit within the habitat-season combinations investigated were included in the meta-analysis.

#	Publications	Compiled in database?	Included in meta-analysis?
81	Roth, A.-M.F., and D.M. Baltz. 2009. Short-term effects of an oil spill on marsh-edge fishes and decapod crustaceans. *Estuaries and Coasts* 32: 565–572.	Yes	Yes
82	Rozas, L.P. 1992. Bottomless lift net for quantitatively sampling nekton on intertidal marshes. *Marine Ecology Progress Series* 89: 287–292.	No; duplicate data	N/A
83	Rozas, L.P., and T.J. Minello. 1997. Structural marsh management effects on habitat selection by nekton. Silver Spring, Maryland: National Marine Fisheries Service.	No; duplicate data	N/A
84	Rozas, L.P., and T.J. Minello. 1998. Nekton use of salt marsh, seagrass, and nonvegetated habitats in a south Texas (USA) estuary. *Bulletin of Marine Science* 63(3): 481–501.	Yes	Yes
85	Rozas, L.P., and T.J. Minello. 1999. Effects of structural marsh management on fishery species and other nekton before and during a spring drawdown. *Wetlands Ecology and Management* 7: 121–139.	Yes	Yes
86	Rozas, L.P., and T.J. Minello. 2001. Marsh terracing as a wetland restoration tool for creating fishery habitat. *Wetlands* 21(3): 327–341.	Yes	Yes
87	Rozas, L.P., and T.J. Minello. 2006. Nekton use of *Vallisneria americana Michx.* (wild celery) beds and adjacent habitats in coastal Louisiana. *Estuaries and Coasts* 29(2): 297–310.	Yes	Yes
88	Rozas, L.P., and T.J. Minello. 2007. Restoring coastal habitat using marsh terracing: The effect of cell size on nekton use. *Wetlands* 27(3): 595–609.	Yes	Yes
89	Rozas, L.P., and T.J. Minello. 2010. Nekton density patterns in tidal ponds and adjacent wetlands related to pond size and salinity. *Estuaries and Coasts* 33: 652–667.	No; duplicate data	N/A
90	Rozas, L.P., and D.J. Reed. 1993. Nekton use of marsh-surface habitats in Louisiana (USA) deltaic salt marshes undergoing submergence. *Marine Ecology Progress Series* 96: 147–157.	Yes	No; data combined
91	Rozas, L.P., and R.J. Zimmerman. 2000. Small-scale patterns of nekton use among marsh and adjacent shallow nonvegetated areas of the Galveston Bay Estuary, Texas (USA). *Marine Ecology Progress Series* 193: 217–239.	Yes	Yes
92	Rozas, L.P., C.W. Martin, and J.F. Valentine. 2013. Effects of reduced hydrological connectivity on the nursery use of shallow estuarine habitats within a river delta. *Marine Ecology Progress Series* 492: 9–20.	Yes	Yes
93	Rozas, L.P., T.J. Minello, and D.D. Dantin. 2012. Use of shallow lagoon habitats by nekton of the northeastern Gulf of Mexico. *Estuaries and Coasts* 35: 572–586.	Yes	Yes

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#	Publications	Compiled in database?	Included in meta-analysis?
94	Rozas, L.P., T.J. Minello, R.J. Zimmerman, and P. Caldwell. 2007. Nekton populations, long-term wetland loss, and the effect of recent habitat restoration in Galveston Bay, Texas. *Marine Ecology Progress Series* 344: 119–130.	Yes	Yes
95	Rozas, L.P., T.J. Minello, I. Munuera-Fernandez, B. Fry, and B. Wissel. 2005. Macrofaunal distributions and habitat change following winter-spring releases of freshwater into the Breton Sound estuary, Louisiana (USA). *Estuarine, Coastal and Shelf Science* 65: 319–336.	Yes	No; data combined
96	Scott, E. 1998. Utilization of submerged aquatic vegetation habitats by fishes and decapods in the Galveston Bay ecosystem, Texas. MS Thesis, Texas A&M University.	Yes	Yes
97	Scyphers, S.B., S.P. Powers, K.L. Heck Jr., and D. Byron. 2011. Oyster reefs as natural breakwaters mitigate shoreline loss and facilitate fisheries. *PLoS ONE* 6(8): e22396.	Yes	No; data combined
98	Sheridan, P. 2004. Comparison of restored and natural seagrass beds near Corpus Christi, Texas. *Estuaries* 27(5): 781–792.	Yes	Yes
99	Sheridan, P., and T.J. Minello. 2003. Nekton use of different habitat types in seagrass beds of lower Laguna Madre, Texas. *Bulletin of Marine Science* 72(1): 37–61.	Yes	Yes
100	Shervette, V.R., and F. Gelwick. 2008. Seasonal and spatial variations in fish and macroinvertebrate communities of oyster and adjacent habitats in a Mississippi estuary. *Estuaries and Coasts* 31: 584–596.	Yes	No; data combined
101	Shervette, V.R., F. Gelwick, and N. Hadley. 2011. Decapod utilization of adjacent oyster, vegetated marsh, and non-vegetated bottom habitats in a Gulf of Mexico estuary. *Journal of Crustacean Biology* 31(4): 660–667.	Yes	Yes
102	Simonsen, K., and J.H. Cowan Jr. 2007. Sport fish utilization of an inshore artificial oyster reef in Barataria Bay, Louisiana. In *Proceedings of the 60th Gulf and Caribbean Fisheries Institute*, 398–406. 5–9 November, Punta Cana, Dominican Republic.	No; duplicate data	N/A
103	Simonsen, K.A. 2008. The effect of an inshore artificial reef on the community structure and feeding ecology of estuarine fishes in Barataria Bay, Louisiana. MS Thesis, Louisiana State University.	Yes	No; no density data
104	Stein III, W. 2013. Fish and decapod community structure in estuarine habitats of the New Orleans Land Bridge, including a description of the life cycle of tarpon (*Megalops atlanticus*) in Southeastern Louisiana. PhD Dissertation, University of New Orleans.	Yes	No; data combined
105	Stoner, A.W. 1983. Distribution of fishes in seagrass meadows: Role of macrophyte biomass and species composition. *Fishery Bulletin* 81(4): 837–846.	Yes	Yes

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#	Publications	Compiled in database?	Included in meta-analysis?
106	Stunz, G.W., T.J. Minello, and L.P. Rozas. 2010. Relative value of oyster reef as habitat for estuarine nekton in Galveston Bay, Texas. *Marine Ecology Progress Series* 406: 147–159.	Yes	Yes
107	Stunz, G., M. Reese, and A. Bushon. 2006. Impacts of a new tidal inlet on estuarine nekton: The opening of Packery Channel in Corpus Christi Texas. Final report to Coastal Bend Bays & Estuaries Program, Corpus Christi, TX. August 17.	No; duplicate data	N/A
108	Subrahmanyam, C.B., and C.L. Coultas. 1980. Studies on the animal communities in two north Florida salt marshes Part III: Seasonal fluctuations of fish and macroinvertebrates. *Bulletin of Marine Science* 30(4): 790–818.	Yes	Yes
109	Subrahmanyam, C.B., and S.H. Drake. 1975. Studies on the animal communities in two north Florida salt marshes. Part I: Fish communities. *Bulletin of Marine Science* 25(4): 445–465.	Yes	Yes
110	Thom, C.S.B., M.K.G. La Peyre, and J.A. Nyman. 2004. Evaluation of nekton use and habitat characteristics of restored Louisiana marsh. *Ecological Engineering* 23: 63–75.	No; duplicate data	N/A
111	Tolley, S.G., and A.K. Volety. 2005. The role of oysters in habitat use of oyster reefs by resident fishes and decapod crustaceans. *Journal of Shellfish Research* 24(4): 1007–1012.	Yes	Yes
112	Valentine, J.F., and K.L. Heck Jr. 1993. Mussels in seagrass meadows: Their influence on macroinvertebrate abundance and secondary production in the northern Gulf of Mexico. *Marine Ecology Progress Series* 96: 63–74.	Yes	No; only report density for groups of taxa
113	Vose, F.E., and S.S. Bell. 1994. Resident fishes and macrobenthos in mangrove-rimmed habitats: Evaluation of habitat restoration by hydrologic modification. *Estuaries* 17(3): 585–596.	Yes	No; does not fit habitat-season combinations
114	Williams, P.R. 1998. Nekton assemblages associated with the Barrier Island aquatic habitats of East Timbalier Island, Louisiana. MS Thesis, Louisiana State University.	Yes	No; data combined
115	Yeldell, N.A., M.K. La Peyre, and S. Beck. 2011. Testing the effect of live oyster presence and structural diversity on nekton abundance and diversity. Louisiana Sea Grant Undergraduate Research Opportunities Program.	Yes	No; does not fit habitat-season combinations
116	Zeug, S.C., V.R. Shervette, D.J. Hoeinghaus, and S.E.I. Davis. 2007. Nekton assemblage structure in natural and created marsh-edge habitats of the Guadalupe Estuary, Texas, USA. *Estuarine, Coastal and Shelf Science* 71: 457–466.	Yes	No; data combined
117	Zimmerman, R., T. Minello, T. Baumer, and M. Castiglione. 1989. Oyster reef as habitat for estuarine macrofauna. NOAA Technical Memorandum NMFS-SEFC-249.	Yes	No; does not fit habitat-season combinations

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#	Publications	Compiled in database?	Included in meta-analysis?
118	Zimmerman, R.J., and T.J. Minello. 1984. Densities of *Penaeus aztecus, Penaeus setiferus*, and other natant macrofauna in a Texas salt marsh. *Estuaries* 7(4A): 421–433.	Yes	Yes
119	Zimmerman, R.J., T.J. Minello, M. Castiglione, and D. Smith. Undated. Use of marsh habitats by fishery organisms along a salinity gradient in Galveston Bay. Southeast Fisheries Center, Galveston, TX. Report to Texas Parks and Wildlife Department Environmental Protection Division, Austin, TX.	No; duplicate data	N/A
120	Zimmerman, R.J., T.J. Minello, M.C. Castiglione, and D.L. Smith. 1990. Utilization of marsh and associated habitats along a salinity gradient in Galveston Bay. NOAA Technical Memorandum NMFS-SEFC-250.	Yes	Yes
121	Zimmerman, R.J., T.J. Minello, D.L. Smith, and J. Kostera. 1990. The use of *Juncus* and *Spartina* marshes by fisheries species in Lavaca Bay, Texas, with reference to effects of floods. NOAA Technical Memorandum NMFS-SEFC-251.	Yes	Yes

Table S7 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB, marsh, oyster reefs, and SAV habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB			**Marsh**			**Oyster reefs**			**SAV**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Spring														
–	**Nekton – total**	**–**	**23.57**	**4.58**	**49**	**88.67**	**10.23**	**65**	**266.71**	**119.52**	**4**	**63.92**	**18.01**	**24**
–	**Crustaceans – total**	**–**	**7.02**	**2.03**	**50**	**79.15**	**10.00**	**65**	**323.72**	**187.75**	**2**	**58.39**	**19.24**	**20**
Alpheidae	Bigclaw snapping shrimp	*Alpheus heterochaelis*	0.08	0.28	13	0.45	0.22	20	10.30	2.31	14	0.65	0.30	15
Portunidae	Blue crab, bluepoint	*Callinectes sapidus*	0.46	0.12	67	2.89	0.29	61	2.08	0.61	16	2.54	0.69	20
Diogenidae	Thinstripe hermit	*Clibanarius vittatus*	1.05	0.64	21	1.34	0.32	33	0.82	0.41	13	0.35	0.58	3
Panopeidae	Gulf grassflat crab	*Dyspanopeus texanus*	0.15	0.28	13	0.45	0.22	20			1	3.98	2.61	14
Panopeidae	Flatback mud crab	*Eurypanopeus depressus*	0.68	0.53	16	0.21	0.26	15	30.54	21.83	18	0.00	0.71	2
Panopeidae	Ridgeback mud crab	*Eurypanopeus turgidus*				0.15	0.38	7			1	0.33	0.71	2
Penaeidae	Brown shrimp, golden shrimp, northern brown shrimp, red shrimp, redtail shrimp	*Farfantepenaeus aztecus*	2.35	0.26	76	12.96	1.15	66	6.94	1.72	2	12.09	4.10	9
Penaeidae	Bait shrimp, northern pink shrimp, pink shrimp, spotted shrimp	*Farfantepenaeus duorarum*	0.05	0.32	10	0.18	0.38	7			1	1.32	0.32	10
Penaeidae	Northern white shrimp, white shrimp	*Litopenaeus setiferus*	0.39	0.19	27	1.90	0.89	34			1	4.93	1.52	7

Table S7 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB, marsh, oyster reefs, and SAV habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB			**Marsh**			**Oyster reefs**			**SAV**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Menippidae	Gulf stone crab	*Menippe adina*			1				0.00	0.29	12			
Menippidae	Florida stone crab	*Menippe mercenaria*	0.00	0.58	3	0.03	0.45	5						
Palaemonidae	Brackish grass shrimp	*Palaemonetes intermedius*	0.10	0.21	23	2.71	1.16	30			1	32.76	22.74	9
Palaemonidae	Eastern grass shrimp, riverine grass shrimp	*Palaemonetes paludosus*												
Palaemonidae	Daggerblade grass shrimp	*Palaemonetes pugio*	1.41	0.93	66	50.98	8.54	62	36.71	23.20	14	30.06	14.47	14
Palaemonidae	Common American prawn, common grass shrimp, marsh grass shrimp, marsh shrimp	*Palaemonetes vulgaris*	0.01	0.28	13	1.45	1.29	23						1
Panopeidae	Atlantic mud crab	*Panopeus herbstii*	0.25	0.35	8	0.15	0.25	16	317.29	79.61	14	0.18	0.38	7
Porcellanidae	Green porcelain crab	*Petrolisthes armatus*	3.74	3.57	4			1	18.56	7.42	16			1
Panopeidae	Harris mud crab, estuarine mud crab	*Rhithropanopeus harrisii*	0.27	0.26	15	0.17	0.28	13			1	2.94	1.76	3
Sesarmidae	Heavy marsh crab, purple marsh crab	*Sesarma reticulatum*	0.01	0.24	18	2.20	1.15	26						
Ocypodidae	–	*Uca* spp.			1	4.86	4.30	4	0.00	0.32	10			
Xanthidae	Mud crabs, pebble crabs, rubble crabs	Xanthidae spp.	2.46	0.71	2			1				0.59	0.58	3
–	**Fish – total**	**–**	**14.44**	**3.67**	**53**	**8.95**	**1.27**	**69**	**60.52**	**35.07**	**2**	**8.22**	**2.70**	**31**

Table S7 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB, marsh, oyster reefs, and SAV habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB			**Marsh**			**Oyster reefs**			**SAV**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Fundulidae	Diamond killifish	*Adinia xenica*	0.00	0.28	13	0.52	0.28	18				0.05	0.58	3
Engraulidae	Bay anchovy	*Anchoa mitchilli*	3.89	2.03	34	0.41	0.20	30	0.02	0.71	2	0.51	0.44	6
Sparidae	Sheepshead	*Archosargus probatocephalus*	0.00	0.41	6	0.10	0.41	6				0.42	0.58	3
Ariidae	Hardhead catfish	*Ariopsis felis*	0.06	0.24	18	0.02	0.28	13						1
Clupeidae	Gulf menhaden, largescale menhaden	*Brevoortia patronus*	9.13	3.35	55	2.02	1.24	46				2.19	1.58	8
Blenniidae	Striped blenny	*Chasmodes bosquianus*			1	0.00	0.71	2	0.28	0.28	13			1
Gobiidae	Darter goby	*Ctenogobius boleosoma*	0.39	0.28	22	3.27	1.84	26	9.58	9.30	13	6.65	3.42	15
Sciaenidae	Sand seatrout	*Cynoscion arenarius*	0.03	0.33	9	0.00	0.38	7						
Sciaenidae	Spotted seatrout	*Cynoscion nebulosus*	0.01	0.24	17	0.01	0.27	14			1	0.13	0.45	5
Cyprinodontidae	Sheepshead minnow, sheepshead pupfish	*Cyprinodon variegatus*	0.39	0.31	23	0.47	0.18	30				0.51	0.44	9
Fundulidae	Gulf killifish	*Fundulus grandis*	0.01	0.18	32	0.40	0.16	40	0.26	0.28	13	0.05	0.41	6
Fundulidae	Bayou killifish	*Fundulus pulvereus*			1	0.49	0.58	3						
Poeciliidae	Mosquitofish, western mosquitofish	*Gambusia affinis*			1	0.04	0.58	3						

Table S7 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB, marsh, oyster reefs, and SAV habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB			**Marsh**			**Oyster reefs**			**SAV**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Gobiesocidae	Skilletfish	*Gobiesox strumosus*	0.68	0.33	13	0.68	0.55	12	0.00	0.29	12			
Gobiidae	Naked goby	*Gobiosoma bosc*	0.63	0.30	34	0.74	0.23	33	0.86	0.55	14	1.19	0.92	5
Sparidae	Pinfish	*Lagodon rhomboides*	0.59	0.21	64	3.18	0.49	54	5.46	2.35	2	5.73	2.55	35
Sciaenidae	Spot	*Leiostomus xanthurus*	1.77	0.58	54	0.23	0.15	46			1	0.34	0.27	14
Fundulidae	Rainwater killifish	*Lucania parva*	0.61	0.61	8	0.41	0.27	14				1.48	1.19	13
Atherinopsidae	Inland silverside, tidewater silverside	*Menidia beryllina*	0.78	0.22	37	0.56	0.19	37	3.88	3.88	2	1.12	0.99	11
Sciaenidae	Atlantic croaker	*Micropogonias undulatus*	0.33	0.18	32	0.02	0.21	22			1	0.12	0.41	6
Mugilidae	Striped mullet, gray mullet, black mullet	*Mugil cephalus*	0.11	0.17	36	0.41	0.16	38			1	0.00	0.45	5
Ophichthidae	Speckled worm eel	*Myrophis punctatus*	0.14	0.22	21	0.18	0.21	22	0.28	0.29	12			1
Batrachoididae	Gulf toadfish	*Opsanus beta*	0.10	0.29	12	0.03	0.29	12	2.84	1.38	14	0.00	0.45	5
Paralichthyidae	Southern flounder	*Paralichthys lethostigma*	0.05	0.20	24	0.12	0.20	25				0.03	0.45	5
Poeciliidae	Sailfin molly	*Poecilia latipinna*	0.00	0.58	3	0.00	0.58	3						
Sciaenidae	Black drum	*Pogonias cromis*	0.08	0.35	8	0.00	0.50	4				0.07	0.71	2
Sciaenidae	Red drum	*Sciaenops ocellatus*	0.03	0.22	21	0.00	0.25	16				0.00	0.71	2

Table S7 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB, marsh, oyster reefs, and SAV habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB			**Marsh**			**Oyster reefs**			**SAV**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Tetraodontidae	Least puffer	*Sphoeroides parvus*	0.06	0.28	13	0.04	0.35	8						
Cynoglossidae	Blackcheek tonguefish	*Symphurus plagiusa*	0.16	0.21	22	0.01	0.24	17				0.22	0.45	5
Fall														
–	**Nekton – total**	**–**	**16.07**	**3.06**	**47**	**115.12**	**10.62**	**59**	**102.95**	**79.64**	**6**	**74.67**	**10.54**	**26**
–	**Crustaceans – total**	**–**	**9.05**	**2.59**	**48**	**104.36**	**10.26**	**59**	**86.35**	**67.84**	**6**	**68.01**	**10.79**	**22**
Alpheidae	Bigclaw snapping shrimp	*Alpheus heterochaelis*	0.17	0.27	14	2.11	1.05	12	4.99	2.34	11	4.01	1.09	21
Portunidae	Blue crab, bluepoint	*Callinectes sapidus*	1.94	0.34	74	12.93	2.18	63	8.05	4.40	13	6.42	2.13	30
Diogenidae	Thinstripe hermit	*Clibanarius vittatus*	0.12	0.28	13	1.30	0.46	21	3.30	2.23	7	0.41	0.71	2
Panopeidae	Gulf grassflat crab	*Dyspanopeus texanus*	0.19	0.29	12	2.90	1.31	13				8.30	3.54	9
Panopeidae	Flatback mud crab	*Eurypanopeus depressus*	0.22	0.45	5	1.13	1.07	8	4.63	3.70	8			1
Panopeidae	Ridgeback mud crab	*Eurypanopeus turgidus*						1			1	0.10	0.71	2
Penaeidae	Brown shrimp, golden shrimp, northern brown shrimp, red shrimp, redtail shrimp	*Farfantepenaeus aztecus*	0.61	0.13	59	6.04	0.90	51	0.65	0.41	6	2.83	0.72	15

Table S7 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB, marsh, oyster reefs, and SAV habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB			**Marsh**			**Oyster reefs**			**SAV**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Penaeidae	Bait shrimp, northern pink shrimp, pink shrimp, spotted shrimp	*Farfantepenaeus duorarum*	0.52	0.14	49	5.00	0.72	36			1	9.51	2.56	15
Penaeidae	Northern white shrimp, white shrimp	*Litopenaeus setiferus*	2.77	0.84	70	12.90	1.95	60	6.59	4.88	7	9.93	3.62	9
Menippidae	Gulf stone crab	*Menippe adina*						1	0.51	0.46	7			1
Menippidae	Florida stone crab	*Menippe mercenaria*			1			1						
Palaemonidae	Brackish grass shrimp	*Palaemonetes intermedius*	0.04	0.18	30	3.44	1.14	38				11.95	2.44	9
Palaemonidae	Eastern grass shrimp, riverine grass shrimp	*Palaemonetes paludosus*			1			1						
Palaemonidae	Daggerblade grass shrimp	*Palaemonetes pugio*	1.75	0.78	49	43.70	5.57	49	1.19	0.78	11	24.40	8.09	15
Palaemonidae	Common American prawn, common grass shrimp, marsh grass shrimp, marsh shrimp	*Palaemonetes vulgaris*	0.08	0.19	29	4.73	1.36	33				4.26	3.04	7
Panopeidae	Atlantic mud crab	*Panopeus herbstii*	0.07	0.29	12	0.03	0.29	12	161.24	65.42	7	0.14	0.41	6
Porcellanidae	Green porcelain crab	*Petrolisthes armatus*	0.00	0.71	2	0.07	0.58	3	0.11	0.38	7			1
Panopeidae	Harris mud crab, estuarine mud crab	*Rhithropanopeus harrisii*	0.44	0.27	14	0.62	0.31	12				0.38	0.71	2
Sesarmidae	Heavy marsh crab, purple marsh crab	*Sesarma reticulatum*	0.01	0.22	20	2.17	1.41	21						

Table S7 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB, marsh, oyster reefs, and SAV habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB			**Marsh**			**Oyster reefs**			**SAV**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Ocypodidae	–	*Uca* spp.	0.00	0.58	3	0.56	0.49	6	1.13	0.56	6			
Xanthidae	Mud crabs, pebble crabs, rubble crabs	Xanthidae spp.	0.08	0.38	7	0.02	0.41	6				0.17	0.71	2
–	**Fish – total**	**–**	**6.11**	**0.98**	**54**	**10.47**	**1.34**	**61**	**16.03**	**7.88**	**6**	**8.92**	**1.56**	**35**
Fundulidae	Diamond killifish	*Adinia xenica*	0.13	0.29	12	1.64	0.68	13				0.09	0.45	5
Engraulidae	Bay anchovy	*Anchoa mitchilli*	3.97	0.86	61	0.40	0.15	42			1	0.08	0.33	9
Sparidae	Sheepshead	*Archosargus probatocephalus*	0.02	0.38	7	0.00	0.58	3	0.25	0.50	4			
Ariidae	Hardhead catfish	*Ariopsis felis*	0.02	0.38	7	0.04	0.58	3						1
Clupeidae	Gulf menhaden, largescale menhaden	*Brevoortia patronus*	0.01	0.30	11	0.06	0.32	10			1	0.02	0.58	3
Blenniidae	Striped blenny	*Chasmodes bosquianus*						1	0.11	0.38	7			1
Gobiidae	Darter goby	*Ctenogobius boleosoma*	0.45	0.15	42	2.04	0.65	39	5.20	4.77	12	6.23	1.33	19
Sciaenidae	Sand seatrout	*Cynoscion arenarius*	0.01	0.58	3			1						
Sciaenidae	Spotted seatrout	*Cynoscion nebulosus*	0.13	0.15	46	0.31	0.17	33				0.23	0.41	6
Cyprinodontidae	Sheepshead minnow, sheepshead pupfish	*Cyprinodon variegatus*	0.44	0.31	26	0.99	0.32	27	0.16	0.45	5	1.59	0.80	14
Fundulidae	Gulf killifish	*Fundulus grandis*	0.03	0.19	28	0.90	0.22	32	0.00	0.41	6	0.33	0.50	4

Table S7 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB, marsh, oyster reefs, and SAV habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB			**Marsh**			**Oyster reefs**			**SAV**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Fundulidae	Bayou killifish	*Fundulus pulvereus*	0.00	0.28	13	0.30	0.27	14				0.00	0.71	2
Poeciliidae	Mosquitofish, western mosquitofish	*Gambusia affinis*			1	0.00	0.58	3						
Gobiesocidae	Skilletfish	*Gobiesox strumosus*	0.00	0.41	6	0.11	0.38	7	0.38	0.32	10			
Gobiidae	Naked goby	*Gobiosoma bosc*	1.15	0.29	45	6.19	1.55	40	1.23	0.46	12	2.13	1.05	9
Sparidae	Pinfish	*Lagodon rhomboides*	0.02	0.20	24	0.35	0.25	18			1	0.59	0.16	37
Sciaenidae	Spot	*Leiostomus xanthurus*	0.13	0.21	23	0.00	0.27	14				0.05	0.50	4
Fundulidae	Rainwater killifish	*Lucania parva*	0.00	0.33	9	1.77	0.73	11				1.36	0.43	18
Atherinopsidae	Inland silverside, tidewater silverside	*Menidia beryllina*	0.50	0.19	29	0.15	0.18	30			1	0.25	0.32	10
Sciaenidae	Atlantic croaker	*Micropogonias undulatus*	0.43	0.16	37	0.04	0.26	15			1	0.14	0.58	3
Mugilidae	Striped mullet, gray mullet, black mullet	*Mugil cephalus*	0.18	0.20	24	0.16	0.18	31	0.00	0.50	4			
Ophichthidae	Speckled worm eel	*Myrophis punctatus*	0.08	0.29	12	0.22	0.29	12	0.16	0.32	10			1
Batrachoididae	Gulf toadfish	*Opsanus beta*	0.02	0.35	8	0.03	0.45	5	0.68	0.62	11	0.05	0.41	6
Paralichthyidae	Southern flounder	*Paralichthys lethostigma*	0.03	0.26	15	0.02	0.26	15	0.00	0.50	4			

Table S7 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB, marsh, oyster reefs, and SAV habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB			**Marsh**			**Oyster reefs**			**SAV**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Poeciliidae	Sailfin molly	*Poecilia latipinna*	0.00	0.33	9	1.78	1.05	5				0.33	0.50	4
Sciaenidae	Black drum	*Pogonias cromis*	0.00	0.50	4	0.00	0.71	2						
Sciaenidae	Red drum	*Sciaenops ocellatus*	0.15	0.18	32	0.16	0.29	12				0.23	0.32	10
Tetraodontidae	Least puffer	*Sphoeroides parvus*	0.03	0.33	9	0.04	0.33	9						
Cynoglossidae	Blackcheek tonguefish	*Symphurus plagiusa*	0.53	0.16	39	0.37	0.16	37	0.22	0.45	5	1.02	0.45	8

Table S8 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB ("near" and "far") and marsh ("edge" and "interior") habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB						**Marsh**					
			Far			**Near**			**Edge**			**Interior**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Spring														
–	**Nekton – total**	**–**	**14.13**	**3.05**	**13**	**31.96**	**8.22**	**25**	**89.13**	**13.57**	**32**	**47.09**	**8.00**	**10**
–	**Crustaceans – total**	**–**	**4.49**	**0.96**	**13**	**9.35**	**3.83**	**26**	**76.33**	**12.98**	**32**	**41.50**	**7.73**	**10**
Alpheidae	Bigclaw snapping shrimp	*Alpheus heterochaelis*				0.12	0.35	8	0.44	0.30	11			1
Portunidae	Blue crab, bluepoint	*Callinectes sapidus*	0.32	0.21	23	0.60	0.19	32	3.44	0.39	40	1.23	0.51	10
Diogenidae	Thinstripe hermit	*Clibanarius vittatus*				1.24	0.80	17	1.49	0.40	18	1.71	1.50	5
Panopeidae	Gulf grassflat crab	*Dyspanopeus texanus*				0.15	0.28	13	0.11	0.35	8	0.00	0.71	2
Panopeidae	Flatback mud crab	*Eurypanopeus depressus*			1	0.06	0.32	10	0.42	0.41	6			1
Panopeidae	Ridgeback mud crab	*Eurypanopeus turgidus*							0.15	0.38	7			
Penaeidae	Brown shrimp, golden shrimp, northern brown shrimp, red shrimp, redtail shrimp	*Farfantepenaeus aztecus*	1.91	0.35	35	3.00	0.41	29	13.41	1.37	45	4.56	1.56	10
Penaeidae	Bait shrimp, northern pink shrimp, pink shrimp, spotted shrimp	*Farfantepenaeus duorarum*	0.04	0.58	3			1	0.18	0.38	7			
Penaeidae	Northern white shrimp, white shrimp	*Litopenaeus setiferus*	0.04	0.50	4	0.61	0.32	16	0.31	0.21	22	0.40	0.50	4
Menippidae	Gulf stone crab	*Menippe adina*						1						

Table S8 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB ("near" and "far") and marsh ("edge" and "interior") habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB						**Marsh**					
			Far			**Near**			**Edge**			**Interior**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Menippidae	Florida stone crab	*Menippe mercenaria*				0.00	0.58	3						
Palaemonidae	Brackish grass shrimp	*Palaemonetes intermedius*	0.00	0.58	3	0.05	0.29	12	3.37	1.78	19	0.00	0.58	3
Palaemonidae	Eastern grass shrimp, riverine grass shrimp	*Palaemonetes paludosus*												
Palaemonidae	Daggerblade grass shrimp	*Palaemonetes pugio*	0.32	0.20	24	2.45	1.92	29	44.05	9.69	41	25.12	6.73	10
Palaemonidae	Common American prawn, common grass shrimp, marsh grass shrimp, marsh shrimp	*Palaemonetes vulgaris*				0.00	0.38	7	0.19	0.29	12	0.29	0.58	3
Panopeidae	Atlantic mud crab	*Panopeus herbstii*				0.22	0.45	5	0.12	0.32	10			1
Porcellanidae	Green porcelain crab	*Petrolisthes armatus*			1	0.22	0.71	2			1			
Panopeidae	Harris mud crab, estuarine mud crab	*Rhithropanopeus harrisii*				0.17	0.30	11	0.29	0.41	6	0.07	0.58	3
Sesarmidae	Heavy marsh crab, purple marsh crab	*Sesarma reticulatum*	0.00	0.41	6	0.00	0.33	9	3.68	2.12	15	1.77	1.35	3
Ocypodidae	–	*Uca* spp.							6.73	6.73	2	1.16	1.22	2
Xanthidae	Mud crabs, pebble crabs, rubble crabs	Xanthidae spp.						1			1			
–	**Fish – total**	**–**	**9.63**	**2.44**	**13**	**19.49**	**6.45**	**29**	**11.34**	**2.14**	**36**	**5.60**	**1.39**	**10**
Fundulidae	Diamond killifish	*Adinia xenica*			1	0.00	0.30	11	0.37	0.32	10	1.32	0.85	4

Table S8 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB ("near" and "far") and marsh ("edge" and "interior") habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB						**Marsh**					
			Far			**Near**			**Edge**			**Interior**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Engraulidae	Bay anchovy	*Anchoa mitchilli*			1	5.19	3.23	21	0.49	0.32	18	0.23	0.50	4
Sparidae	Sheepshead	*Archosargus probatocephalus*			1	0.00	0.50	4			1			
Ariidae	Hardhead catfish	*Ariopsis felis*				0.09	0.28	13	0.00	0.50	4	0.00	0.58	3
Clupeidae	Gulf menhaden, largescale menhaden	*Brevoortia patronus*	8.12	1.97	18	12.45	6.18	28	3.13	2.03	28	0.70	0.63	8
Blenniidae	Striped blenny	*Chasmodes bosquianus*							0.00	0.71	2			
Gobiidae	Darter goby	*Ctenogobius boleosoma*			1	0.51	0.36	17	4.68	2.71	18	1.14	1.22	2
Sciaenidae	Sand seatrout	*Cynoscion arenarius*				0.05	0.41	6	0.00	0.58	3			1
Sciaenidae	Spotted seatrout	*Cynoscion nebulosus*			1	0.00	0.28	13	0.01	0.32	10			1
Cyprinodontidae	Sheepshead minnow, sheepshead pupfish	*Cyprinodon variegatus*			1	0.10	0.24	18	0.29	0.24	17	1.76	0.75	5
Fundulidae	Gulf killifish	*Fundulus grandis*	0.00	0.50	4	0.01	0.21	22	0.25	0.21	23	0.85	0.41	6
Fundulidae	Bayou killifish	*Fundulus pulvereus*									1	0.22	1.22	2
Poeciliidae	Mosquitofish, western mosquitofish	*Gambusia affinis*									1	0.00	1.22	2
Gobiesocidae	Skilletfish	*Gobiesox strumosus*				0.38	0.32	10	1.31	1.08	6	0.00	0.58	3
Gobiidae	Naked goby	*Gobiosoma bosc*	0.18	0.50	4	0.77	0.44	22	0.70	0.35	20	0.00	0.50	4

Table S8 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB ("near" and "far") and marsh ("edge" and "interior") habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB						**Marsh**					
			Far			**Near**			**Edge**			**Interior**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Sparidae	Pinfish	*Lagodon rhomboides*	0.34	0.20	25	0.19	0.20	26	4.23	0.65	37	1.50	0.91	6
Sciaenidae	Spot	*Leiostomus xanthurus*	0.49	0.28	13	0.35	0.20	24	0.33	0.18	30	0.04	0.45	5
Fundulidae	Rainwater killifish	*Lucania parva*			1	0.00	0.41	6	0.52	0.34	11	0.07	1.22	2
Atherinopsidae	Inland silverside, tidewater silverside	*Menidia beryllina*	0.11	0.50	4	0.94	0.32	25	0.74	0.30	20	0.17	0.41	6
Sciaenidae	Atlantic croaker	*Micropogonias undulatus*	0.64	0.50	4	0.38	0.23	19	0.02	0.26	15	0.06	0.50	4
Mugilidae	Striped mullet, gray mullet, black mullet	*Mugil cephalus*	0.02	0.38	7	0.15	0.21	22	0.40	0.21	22	0.74	0.35	8
Ophichthidae	Speckled worm eel	*Myrophis punctatus*				0.13	0.24	17	0.23	0.28	13	0.12	0.58	3
Batrachoididae	Gulf toadfish	*Opsanus beta*			1	0.12	0.32	10	0.03	0.35	8			1
Paralichthyidae	Southern flounder	*Paralichthys lethostigma*			1	0.05	0.24	17	0.09	0.29	12	0.00	0.71	2
Poeciliidae	Sailfin molly	*Poecilia latipinna*				0.00	0.71	2			1	0.00	1.22	2
Sciaenidae	Black drum	*Pogonias cromis*			1	0.09	0.38	7	0.00	0.50	4			
Sciaenidae	Red drum	*Sciaenops ocellatus*			1	0.04	0.25	16	0.00	0.33	9			1
Tetraodontidae	Least puffer	*Sphoeroides parvus*				0.09	0.33	9	0.12	0.58	3	0.00	0.71	2
Cynoglossidae	Blackcheek tonguefish	*Symphurus plagiusa*	0.69	0.50	4	0.04	0.26	15	0.00	0.32	10			1

Table S8 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB ("near" and "far") and marsh ("edge" and "interior") habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB						**Marsh**					
			Far			**Near**			**Edge**			**Interior**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Fall														
–	**Nekton – total**	**–**	**8.47**	**1.19**	**16**	**21.80**	**5.44**	**25**	**103.06**	**9.57**	**27**	**55.91**	**11.74**	**9**
–	**Crustaceans – total**	**–**	**4.35**	**0.63**	**16**	**12.83**	**4.85**	**25**	**93.79**	**10.16**	**27**	**45.63**	**10.53**	**9**
Alpheidae	Bigclaw snapping shrimp	*Alpheus heterochaelis*	0.10	0.50	4	0.08	0.35	8	4.73	2.78	4			
Portunidae	Blue crab, bluepoint	*Callinectes sapidus*	1.49	0.19	38	2.64	0.76	28	11.53	1.22	41	3.69	1.04	11
Diogenidae	Thinstripe hermit	*Clibanarius vittatus*				0.13	0.29	12	1.57	0.96	8	2.63	2.58	3
Panopeidae	Gulf grassflat crab	*Dyspanopeus texanus*				0.19	0.29	12	0.56	0.71	2	0.00	0.71	2
Panopeidae	Flatback mud crab	*Eurypanopeus depressus*				0.00	0.50	4	4.29	4.29	2			
Panopeidae	Ridgeback mud crab	*Eurypanopeus turgidus*									1			
Penaeidae	Brown shrimp, golden shrimp, northern brown shrimp, red shrimp, redtail shrimp	*Farfantepenaeus aztecus*	0.47	0.20	26	0.72	0.20	26	7.36	1.31	31	1.07	0.37	9
Penaeidae	Bait shrimp, northern pink shrimp, pink shrimp, spotted shrimp	*Farfantepenaeus duorarum*	0.54	0.20	25	0.37	0.25	16	3.22	0.62	23	0.18	0.71	2
Penaeidae	Northern white shrimp, white shrimp	*Litopenaeus setiferus*	1.11	0.31	38	4.84	1.92	26	17.77	2.73	38	4.93	2.06	11
Menippidae	Gulf stone crab	*Menippe adina*									1			

Table S8 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB ("near" and "far") and marsh ("edge" and "interior") habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB						**Marsh**					
			Far			**Near**			**Edge**			**Interior**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Menippidae	Florida stone crab	*Menippe mercenaria*						1						
Palaemonidae	Brackish grass shrimp	*Palaemonetes intermedius*	0.01	0.41	6	0.03	0.24	17	5.00	2.11	20	0.85	0.38	7
Palaemonidae	Eastern grass shrimp, riverine grass shrimp	*Palaemonetes paludosus*									1			
Palaemonidae	Daggerblade grass shrimp	*Palaemonetes pugio*	0.21	0.26	15	2.98	1.43	26	43.10	6.40	27	24.77	6.61	11
Palaemonidae	Common American prawn, common grass shrimp, marsh grass shrimp, marsh shrimp	*Palaemonetes vulgaris*	0.16	0.38	7	0.07	0.24	17	4.56	1.99	15	0.18	0.38	7
Panopeidae	Atlantic mud crab	*Panopeus herbstii*				0.07	0.29	12	0.00	0.71	2			1
Porcellanidae	Green porcelain crab	*Petrolisthes armatus*				0.00	0.71	2			1			
Panopeidae	Harris mud crab, estuarine mud crab	*Rhithropanopeus harrisii*	0.74	0.58	3	0.08	0.33	9	1.10	0.58	6	0.07	0.58	3
Sesarmidae	Heavy marsh crab, purple marsh crab	*Sesarma reticulatum*	0.04	0.58	3	0.00	0.25	16	4.42	3.20	9	1.28	1.09	4
Ocypodidae	–	*Uca* spp.				0.00	0.71	2	1.45	1.22	2	0.07	1.22	2
Xanthidae	Mud crabs, pebble crabs, rubble crabs	Xanthidae spp.				0.00	0.41	6	0.04	0.58	3	0.00	0.71	2
–	**Fish – total**	**–**	**4.12**	**0.97**	**16**	**8.39**	**1.73**	**27**	**8.84**	**1.54**	**29**	**10.27**	**3.10**	**9**
Fundulidae	Diamond killifish	*Adinia xenica*	0.00	0.71	2	0.23	0.38	7	2.21	1.91	4	2.93	0.50	4

Table S8 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB ("near" and "far") and marsh ("edge" and "interior") habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB						**Marsh**					
			Far			**Near**			**Edge**			**Interior**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Engraulidae	Bay anchovy	*Anchoa mitchilli*	3.65	0.94	26	5.21	1.72	25	0.28	0.20	25	0.07	0.41	6
Sparidae	Sheepshead	*Archosargus probatocephalus*	0.00	0.71	2	0.04	0.58	3						
Ariidae	Hardhead catfish	*Ariopsis felis*				0.03	0.45	5						
Clupeidae	Gulf menhaden, largescale menhaden	*Brevoortia patronus*			1	0.01	0.38	7	0.08	0.35	8	0.00	1.22	2
Blenniidae	Striped blenny	*Chasmodes bosquianus*									1			
Gobiidae	Darter goby	*Ctenogobius boleosoma*	0.41	0.30	11	0.50	0.24	26	2.44	1.05	22	0.60	0.41	6
Sciaenidae	Sand seatrout	*Cynoscion arenarius*				0.01	0.71	2			1			
Sciaenidae	Spotted seatrout	*Cynoscion nebulosus*			1	0.14	0.16	40	0.41	0.26	15	0.09	0.38	7
Cyprinodontidae	Sheepshead minnow, sheepshead pupfish	*Cyprinodon variegatus*	0.06	0.38	7	0.65	0.48	17	0.61	0.35	13	2.78	0.84	7
Fundulidae	Gulf killifish	*Fundulus grandis*	0.11	0.50	4	0.02	0.24	17	0.43	0.24	17	1.35	0.43	7
Fundulidae	Bayou killifish	*Fundulus pulvereus*			1	0.00	0.30	11	0.70	0.70	3	0.40	0.50	4
Poeciliidae	Mosquitofish, western mosquitofish	*Gambusia affinis*									1	0.00	1.22	2
Gobiesocidae	Skilletfish	*Gobiesox strumosus*	0.00	0.71	2	0.00	0.50	4			1			
Gobiidae	Naked goby	*Gobiosoma bosc*	0.91	0.39	13	1.18	0.39	26	3.85	1.25	23	5.75	4.29	6

Table S8 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of individual crustacean and fish species in open-water NVB ("near" and "far") and marsh ("edge" and "interior") habitats during spring and fall in the saline zone. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Open-water NVB						**Marsh**					
			Far			**Near**			**Edge**			**Interior**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Sparidae	Pinfish	*Lagodon rhomboides*	0.02	0.45	5	0.02	0.30	11	0.49	0.35	13			1
Sciaenidae	Spot	*Leiostomus xanthurus*	0.14	0.58	3	0.05	0.29	12	0.00	0.35	8			1
Fundulidae	Rainwater killifish	*Lucania parva*	0.00	0.71	2	0.00	0.50	4	2.01	0.87	9	0.70	0.71	2
Atherinopsidae	Inland silverside, tidewater silverside	*Menidia beryllina*	0.01	0.58	3	0.53	0.22	20	0.16	0.26	15	0.20	0.38	7
Sciaenidae	Atlantic croaker	*Micropogonias undulatus*	0.64	0.71	2	0.47	0.19	31	0.04	0.33	9	0.00	0.71	2
Mugilidae	Striped mullet, gray mullet, black mullet	*Mugil cephalus*	0.72	0.72	2	0.18	0.25	16	0.13	0.26	15	0.32	0.35	8
Ophichthidae	Speckled worm eel	*Myrophis punctatus*	0.00	0.71	2	0.08	0.41	6	0.06	0.41	6			
Batrachoididae	Gulf toadfish	*Opsanus beta*	0.00	0.58	3	0.03	0.50	4	0.00	0.50	4			
Paralichthyidae	Southern flounder	*Paralichthys lethostigma*	0.00	0.71	2	0.04	0.32	10	0.02	0.35	8	0.00	0.71	2
Poeciliidae	Sailfin molly	*Poecilia latipinna*	0.00	0.71	2	0.00	0.50	4			1	2.40	1.22	2
Sciaenidae	Black drum	*Pogonias cromis*				0.00	0.50	4	0.00	0.71	2			
Sciaenidae	Red drum	*Sciaenops ocellatus*	0.10	0.71	2	0.16	0.19	27	0.24	0.38	7	0.13	1.22	2
Tetraodontidae	Least puffer	*Sphoeroides parvus*				0.03	0.33	9						
Cynoglossidae	Blackcheek tonguefish	*Symphurus plagiusa*	0.68	0.32	10	0.48	0.20	26	0.38	0.23	19	0.10	0.38	7

Table S9 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of crustacean and fish species in saline, brackish, and intermediate marsh during spring and fall. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Saline marsh			**Brackish marsh**			**Intermediate marsh**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Spring											
–	**Nekton – total**	**–**	**88.67**	**10.23**	**65**	**41.14**	**15.12**	**11**	**44.24**	**9.72**	**14**
–	**Crustaceans – total**	**–**	**79.15**	**10.00**	**65**	**30.02**	**14.48**	**11**	**24.11**	**11.40**	**10**
Alpheidae	Bigclaw snapping shrimp	*Alpheus heterochaelis*	0.45	0.22	20			1			1
Portunidae	Blue crab, bluepoint	*Callinectes sapidus*	2.89	0.29	61	1.85	0.60	11	0.46	0.28	13
Diogenidae	Thinstripe hermit	*Clibanarius vittatus*	1.34	0.32	33	0.00	0.58	3			1
Panopeidae	Gulf grassflat crab	*Dyspanopeus texanus*	0.45	0.22	20	0.20	0.50	4			
Panopeidae	Flatback mud crab	*Eurypanopeus depressus*	0.21	0.26	15			1			1
Panopeidae	Ridgeback mud crab	*Eurypanopeus turgidus*	0.15	0.38	7						
Penaeidae	Brown shrimp, golden shrimp, northern brown shrimp, red shrimp, redtail shrimp	*Farfantepenaeus aztecus*	12.96	1.15	66	1.85	0.75	10	0.12	0.41	6
Penaeidae	Bait shrimp, northern pink shrimp, pink shrimp, spotted shrimp	*Farfantepenaeus duorarum*	0.18	0.38	7			1			1
Penaeidae	Northern white shrimp, white shrimp	*Litopenaeus setiferus*	1.90	0.89	34	0.00	0.58	3			1
Menippidae	Gulf stone crab	*Menippe adina*							0.02	0.71	2
Menippidae	Florida stone crab	*Menippe mercenaria*	0.03	0.45	5						
Palaemonidae	Brackish grass shrimp	*Palaemonetes intermedius*	2.71	1.16	30	0.32	0.45	5			1
Palaemonidae	Eastern grass shrimp, riverine grass shrimp	*Palaemonetes paludosus*							15.31	6.51	10
Palaemonidae	Daggerblade grass shrimp	*Palaemonetes pugio*	50.98	8.54	62	25.08	13.83	11	2.31	1.79	7

Table S9 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of crustacean and fish species in saline, brackish, and intermediate marsh during spring and fall. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Saline marsh			**Brackish marsh**			**Intermediate marsh**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Palaemonidae	Common American prawn, common grass shrimp, marsh grass shrimp, marsh shrimp	*Palaemonetes vulgaris*	1.45	1.29	23	0.00	0.50	4			
Panopeidae	Atlantic mud crab	*Panopeus herbstii*	0.15	0.25	16			1			1
Porcellanidae	Green porcelain crab	*Petrolisthes armatus*			1						
Panopeidae	Harris mud crab, estuarine mud crab	*Rhithropanopeus harrisii*	0.17	0.28	13	0.69	0.56	6	1.61	0.98	6
Sesarmidae	Heavy marsh crab, purple marsh crab	*Sesarma reticulatum*	2.20	1.15	26			1			1
Ocypodidae	–	*Uca* spp.	4.86	4.30	4	1.37	0.69	5	0.06	0.50	4
Xanthidae	Mud crabs, pebble crabs, rubble crabs	Xanthidae spp.			1			1	3.71	3.71	2
–	**Fish – total**	**–**	**8.95**	**1.27**	**69**	**11.12**	**3.58**	**11**	**19.87**	**5.18**	**10**
Fundulidae	Diamond killifish	*Adinia xenica*	0.52	0.28	18	0.63	0.37	10	0.09	0.50	4
Engraulidae	Bay anchovy	*Anchoa mitchilli*	0.41	0.20	30	5.81	4.01	6	0.06	0.50	4
Sparidae	Sheepshead	*Archosargus probatocephalus*	0.10	0.41	6						
Ariidae	Hardhead catfish	*Ariopsis felis*	0.02	0.28	13	0.03	0.50	4	0.01	0.71	2
Clupeidae	Gulf menhaden, largescale menhaden	*Brevoortia patronus*	2.02	1.24	46	0.38	0.41	6	24.28	24.35	6
Blenniidae	Striped blenny	*Chasmodes bosquianus*	0.00	0.71	2			1			1
Gobiidae	Darter goby	*Ctenogobius boleosoma*	3.27	1.84	26	0.51	0.71	2	0.06	0.71	2
Gobiidae	Freshwater goby	*Ctenogobius shufeldti*									1
Sciaenidae	Sand seatrout	*Cynoscion arenarius*	0.00	0.38	7			1			1
Sciaenidae	Spotted seatrout	*Cynoscion nebulosus*	0.01	0.27	14	0.29	0.71	2			

Table S9 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of crustacean and fish species in saline, brackish, and intermediate marsh during spring and fall. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Saline marsh			**Brackish marsh**			**Intermediate marsh**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Cyprinodontidae	Sheepshead minnow, sheepshead pupfish	*Cyprinodon variegatus*	0.47	0.18	30	2.66	1.52	9	5.25	3.12	10
Fundulidae	Gulf killifish	*Fundulus grandis*	0.40	0.16	40	0.62	0.30	11	0.06	0.71	2
Fundulidae	Bayou killifish	*Fundulus pulvereus*	0.49	0.58	3	1.45	0.54	6	0.57	0.33	9
Poeciliidae	Mosquitofish, western mosquitofish	*Gambusia affinis*	0.04	0.58	3	0.05	0.41	6	2.10	1.03	9
Gobiesocidae	Skilletfish	*Gobiesox strumosus*	0.68	0.55	12	0.54	0.54	5			1
Gobiidae	Naked goby	*Gobiosoma bosc*	0.74	0.23	33	2.19	1.51	6	0.27	0.38	7
Sparidae	Pinfish	*Lagodon rhomboides*	3.18	0.49	54	0.45	0.41	6	0.17	0.71	2
Sciaenidae	Spot	*Leiostomus xanthurus*	0.23	0.15	46	0.10	0.38	7	0.04	0.58	3
Fundulidae	Rainwater killifish	*Lucania parva*	0.41	0.27	14	0.58	0.60	6	7.32	1.58	12
Atherinopsidae	Inland silverside, tidewater silverside	*Menidia beryllina*	0.56	0.19	37	0.11	0.32	10	0.39	0.41	6
Sciaenidae	Atlantic croaker	*Micropogonias undulatus*	0.02	0.21	22	0.05	0.38	7	0.00	0.50	4
Mugilidae	Striped mullet, gray mullet, black mullet	*Mugil cephalus*	0.41	0.16	38	0.04	0.30	11	0.00	0.71	2
Ophichthidae	Speckled worm eel	*Myrophis punctatus*	0.18	0.21	22	0.07	0.38	7	0.08	0.58	3
Batrachoididae	Gulf toadfish	*Opsanus beta*	0.03	0.29	12	0.00	0.58	3			1
Paralichthyidae	Southern flounder	*Paralichthys lethostigma*	0.12	0.20	25	0.03	0.45	5	0.00	0.71	2
Poeciliidae	Sailfin molly	*Poecilia latipinna*	0.00	0.58	3	0.09	0.45	5	0.87	0.39	8
Sciaenidae	Black drum	*Pogonias cromis*	0.00	0.50	4						
Sciaenidae	Red drum	*Sciaenops ocellatus*	0.00	0.25	16	0.04	0.58	3			1
Tetraodontidae	Least puffer	*Sphoeroides parvus*	0.04	0.35	8	0.00	0.45	5			1

Table S9 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of crustacean and fish species in saline, brackish, and intermediate marsh during spring and fall. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Saline marsh			**Brackish marsh**			**Intermediate marsh**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Cynoglossidae	Blackcheek tonguefish	*Symphurus plagiusa*	0.01	0.24	17	0.00	0.71	2			1
Fall											
–	**Nekton – total**	**–**	**115.12**	**10.62**	**59**	**90.38**	**36.84**	**11**	**67.12**	**49.09**	**3**
–	**Crustaceans – total**	**–**	**104.36**	**10.26**	**59**	**71.87**	**37.66**	**11**	**45.61**	**45.27**	**3**
Alpheidae	Bigclaw snapping shrimp	*Alpheus heterochaelis*	2.11	1.05	12			1			
Portunidae	Blue crab, bluepoint	*Callinectes sapidus*	12.93	2.18	63	10.06	5.26	11	2.56	1.44	4
Diogenidae	Thinstripe hermit	*Clibanarius vittatus*	1.30	0.46	21			1			1
Panopeidae	Gulf grassflat crab	*Dyspanopeus texanus*	2.90	1.31	13	0.64	0.46	6			1
Panopeidae	Flatback mud crab	*Eurypanopeus depressus*	1.13	1.07	8			1			
Panopeidae	Ridgeback mud crab	*Eurypanopeus turgidus*			1						
Penaeidae	Brown shrimp, golden shrimp, northern brown shrimp, red shrimp, redtail shrimp	*Farfantepenaeus aztecus*	6.04	0.90	51	1.36	0.46	7	0.00	0.71	2
Penaeidae	Bait shrimp, northern pink shrimp, pink shrimp, spotted shrimp	*Farfantepenaeus duorarum*	5.00	0.72	36	1.24	0.68	7	0.00	0.71	2
Penaeidae	Northern white shrimp, white shrimp	*Litopenaeus setiferus*	12.90	1.95	60	0.85	0.33	11	1.42	1.17	4
Menippidae	Gulf stone crab	*Menippe adina*			1						
Menippidae	Florida stone crab	*Menippe mercenaria*			1			1			
Palaemonidae	Brackish grass shrimp	*Palaemonetes intermedius*	3.44	1.14	38	2.85	2.29	6	0.29	0.71	2
Palaemonidae	Eastern grass shrimp, riverine grass shrimp	*Palaemonetes paludosus*			1			1	3.08	3.08	2
Palaemonidae	Daggerblade grass shrimp	*Palaemonetes pugio*	43.70	5.57	49	50.19	27.85	11	8.44	5.19	4

Table S9 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of crustacean and fish species in saline, brackish, and intermediate marsh during spring and fall. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Saline marsh			**Brackish marsh**			**Intermediate marsh**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Palaemonidae	Common American prawn, common grass shrimp, marsh grass shrimp, marsh shrimp	*Palaemonetes vulgaris*	4.73	1.36	33	9.91	9.84	4	2.24	1.65	3
Panopeidae	Atlantic mud crab	*Panopeus herbstii*	0.03	0.29	12	0.07	0.58	3			
Porcellanidae	Green porcelain crab	*Petrolisthes armatus*	0.07	0.58	3						
Panopeidae	Harris mud crab, estuarine mud crab	*Rhithropanopeus harrisii*	0.62	0.31	12	0.45	0.38	7	12.97	12.48	4
Sesarmidae	Heavy marsh crab, purple marsh crab	*Sesarma reticulatum*	2.17	1.41	21	0.37	0.45	5			1
Ocypodidae	–	*Uca* spp.	0.56	0.49	6	0.29	0.45	5			1
Xanthidae	Mud crabs, pebble crabs, rubble crabs	Xanthidae spp.	0.02	0.41	6	0.14	0.41	6	24.43	24.49	2
–	**Fish – total**	**–**	**10.47**	**1.34**	**61**	**18.50**	**4.27**	**11**	**21.51**	**4.11**	**3**
Fundulidae	Diamond killifish	*Adinia xenica*	1.64	0.68	13	3.82	0.45	5			1
Engraulidae	Bay anchovy	*Anchoa mitchilli*	0.40	0.15	42	1.55	0.84	7	0.00	0.58	3
Sparidae	Sheepshead	*Archosargus probatocephalus*	0.00	0.58	3						
Ariidae	Hardhead catfish	*Ariopsis felis*	0.04	0.58	3						
Clupeidae	Gulf menhaden, largescale menhaden	*Brevoortia patronus*	0.06	0.32	10						
Blenniidae	Striped blenny	*Chasmodes bosquianus*			1						
Gobiidae	Darter goby	*Ctenogobius boleosoma*	2.04	0.65	39	0.00	0.41	6	0.64	0.71	2
Gobiidae	Freshwater goby	*Ctenogobius shufeldti*									
Sciaenidae	Sand seatrout	*Cynoscion arenarius*			1			1			1
Sciaenidae	Spotted seatrout	*Cynoscion nebulosus*	0.31	0.17	33	0.05	0.30	11	0.00	0.71	2

Table S9 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of crustacean and fish species in saline, brackish, and intermediate marsh during spring and fall. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Saline marsh			**Brackish marsh**			**Intermediate marsh**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Cyprinodontidae	Sheepshead minnow, sheepshead pupfish	*Cyprinodon variegatus*	0.99	0.32	27	1.75	1.16	10	9.35	4.71	2
Fundulidae	Gulf killifish	*Fundulus grandis*	0.90	0.22	32	0.36	0.30	11	0.64	0.71	2
Fundulidae	Bayou killifish	*Fundulus pulvereus*	0.30	0.27	14	2.21	1.14	10	3.54	3.54	2
Poeciliidae	Mosquitofish, western mosquitofish	*Gambusia affinis*	0.00	0.58	3	0.67	0.45	5			1
Gobiesocidae	Skilletfish	*Gobiesox strumosus*	0.11	0.38	7			1			
Gobiidae	Naked goby	*Gobiosoma bosc*	6.19	1.55	40	11.77	2.80	6	2.67	2.12	3
Sparidae	Pinfish	*Lagodon rhomboides*	0.35	0.25	18	0.00	0.71	2			
Sciaenidae	Spot	*Leiostomus xanthurus*	0.00	0.27	14	0.00	0.58	3			1
Fundulidae	Rainwater killifish	*Lucania parva*	1.77	0.73	11	6.27	6.27	2	4.61	2.04	4
Atherinopsidae	Inland silverside, tidewater silverside	*Menidia beryllina*	0.15	0.18	30	0.06	0.32	10			1
Sciaenidae	Atlantic croaker	*Micropogonias undulatus*	0.04	0.26	15	0.06	0.41	6			1
Mugilidae	Striped mullet, gray mullet, black mullet	*Mugil cephalus*	0.16	0.18	31	0.01	0.33	9	0.58	0.58	3
Ophichthidae	Speckled worm eel	*Myrophis punctatus*	0.22	0.29	12	0.00	0.71	2	1.45	1.45	2
Batrachoididae	Gulf toadfish	*Opsanus beta*	0.03	0.45	5	0.00	0.71	2			1
Paralichthyidae	Southern flounder	*Paralichthys lethostigma*	0.02	0.26	15	0.07	0.45	5			
Poeciliidae	Sailfin molly	*Poecilia latipinna*	1.78	1.05	5	4.80	1.88	5			1
Sciaenidae	Black drum	*Pogonias cromis*	0.00	0.71	2						
Sciaenidae	Red drum	*Sciaenops ocellatus*	0.16	0.29	12			1			
Tetraodontidae	Least puffer	*Sphoeroides parvus*	0.04	0.33	9			1			

Table S9 Estimated means, number of individuals / m^2, (± 1 SE) of total nekton density (sum of crustacean and fish species), total crustacean density, total fish density, and densities of crustacean and fish species in saline, brackish, and intermediate marsh during spring and fall. Means are presented for two or more observations. The total number of samples (N) is also provided.

			Saline marsh			**Brackish marsh**			**Intermediate marsh**		
Family	**Common name**	**Scientific name**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**
Cynoglossidae	Blackcheek tonguefish	*Symphurus plagiusa*	0.37	0.16	37	0.67	0.62	5			

Figures

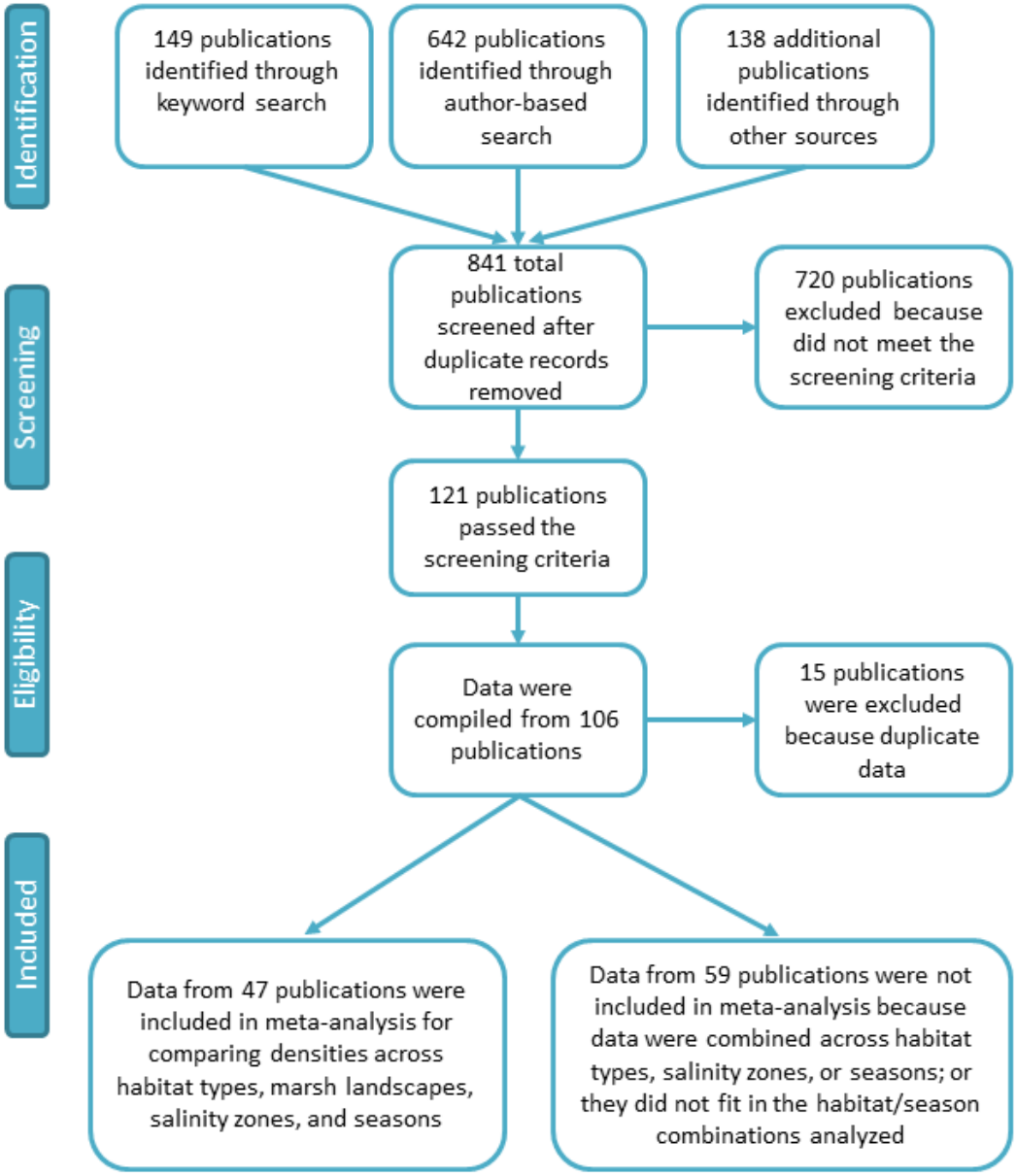

Fig. S1 PRISMA diagram representing the literature search and data compilation process. At each phase moving down through the figure, publications were evaluated and selected or rejected based on how closely they met our screening criteria. The final statistical analysis included data from 47 publications.

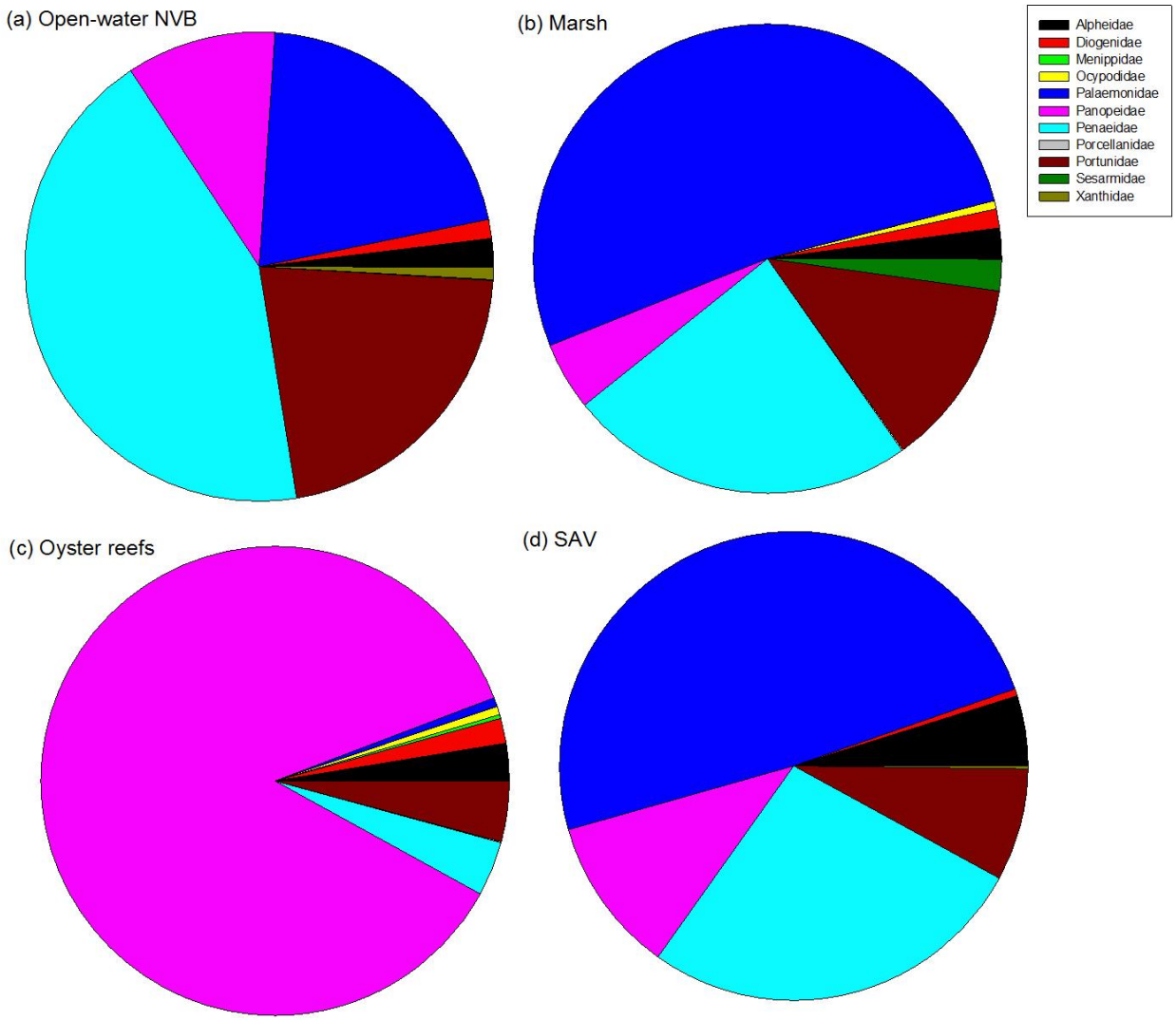

Fig. S2 Relative abundance of crustacean families in the fall by habitat type. Wedge size corresponds to the proportional densities of each family relative to the total family densities for each habitat type reported in fall. Habitat types include (a) open-water NVB, (b) marsh, (c) oyster reefs, and (d) SAV during fall. For comparison, this analysis was limited to sampling conducted in the saline zone.

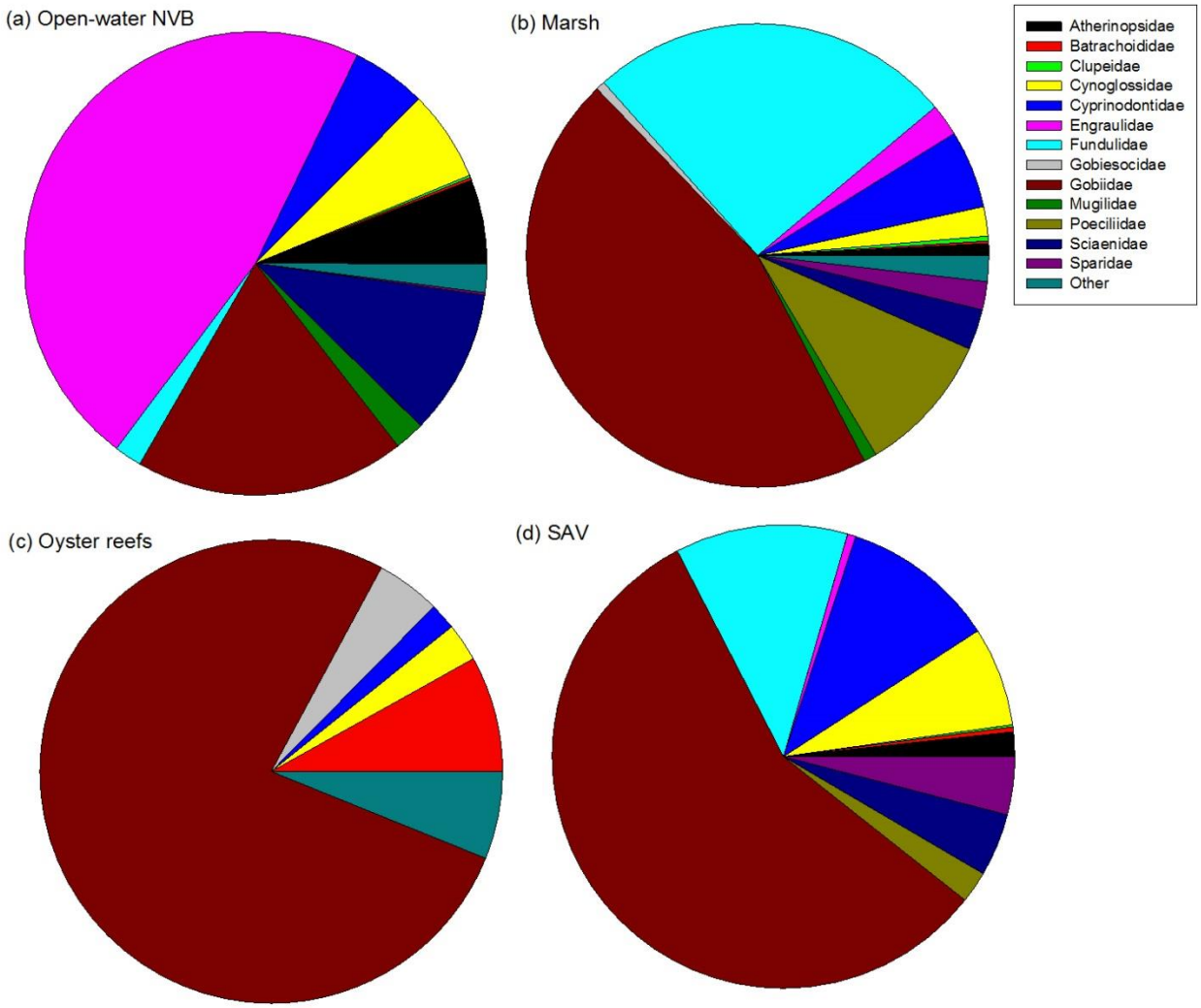

Fig. S3 Relative abundance of fish families in the fall by habitat type. Wedge size corresponds to the proportional densities of each family relative to the total family densities for each habitat type reported in fall. Habitat types include (a) open-water NVB, (b) marsh, (c) oyster reefs, and (d) SAV during fall. For comparison, this analysis was limited to sampling conducted in the saline zone.

Supplement 2: Gear Efficiency Data Compilation

Overview

We conducted a literature search and data compilation of gear efficiency and recovery values to develop a gear-efficiency factor to apply to the nekton density data within the database.

The dataset includes several gear types that can be divided into three main categories: enclosure, towed, and passive (Rozas and Minello 1997). Enclosure gears rapidly enclose and towed gears swipe an area of the bottom and overlying water column, and passive gears are deployed and left in place to capture nekton. The specific gear types included in the database are block net, drop net, throw trap, drop sampler, lift net, and cast net (enclosure); otter trawl, beam trawl, hand trawl, seine, push trawl, and epibenthic sled (towed); and substrate tray (passive). These gear types vary in their ability to capture nekton given their inherent structural characteristics and operational procedures. In addition, capture ability for one given type of gear may also vary across different habitats (Rozas and Minello 1997).

Methods

Literature Search

An initial broad literature search was conducted to identify articles providing information on gear efficiency. The search for gear-efficiency values was guided by the recommended gear-habitat combinations in Rozas and Minello (1997) and the gear-habitat combinations in the nekton utilization database (see Section 2.1 in the main document). Using Google Scholar (https://scholar.google.com/) and Ebscohost (https://www.ebscohost.com/), additional targeted searches were conducted, aimed at filling in the gaps in efficiency data for recommended gear types and habitat combinations.

The literature review included searches for references containing keywords involving gear-habitat combinations with either “efficiency” or “recovery” (e.g., purse seine efficiency seagrass). Additional searches included each gear type followed by “gear efficiency,” “gear recovery,” “efficiency rate,” and “recovery rate”; or “capture efficiency of fishing gear,” “gear selection,” “gear recommendations,” and “retention of catch.” Efforts were focused on collecting efficiency estimates for the sampling gear types and habitats included in the nekton utilization

database, such as drop sampler, throw trap, seine, lift net, substrate tray, gill net, beam trawl, otter trawl, hand trawl, passive trap, epibenthic sled, cast net, and drop net. Identified references were then screened for reported efficiency values for each of the gear types listed above in the following habitats: non-vegetated bottom (NVB), marsh, submerged aquatic vegetation (SAV) or seagrass, oyster reef, and mangrove.

Data Compilation

The following types of information from each study were extracted: gear type and dimensions (gear size, mesh size), gear category (towed, enclosure, passive), habitat type, species, organism size(s), efficiency type (capture, recovery), efficiency value (percent) and standard error (if reported), study type (methods), organism sample size, and number of gear deployments. Several papers provided mean efficiency values but not their standard errors (SEs). For these cases, we used an imputation method similar to the one used to estimate the SEs for nekton density entries (see Section 2.3.1, SE Imputation, in the main document). Both capture and recovery efficiency values were used in the regression between standard deviation (SD) and mean values. Although the regression was quadratic, conventional diagnostics showed it to be appropriate, and thus we used it to impute missing SEs.

A total of 42 references reported capture or recovery efficiency values (Table S1). These mean values corresponded to different species and locations across studies. Due to this, we did not make any efforts to weight these within-study mean values by their SE or sample size when calculating the overall mean across studies. We calculated mean efficiency values across studies for each combination of gear and habitat (i.e., mean of means). Assuming independence among studies, the SE for this across-study mean value was calculated as:

$$SE_{across-study\ mean} = \sqrt{\frac{1}{n^2}\left(SE^2_{study\ 1} + SE^2_{study\ 2} + \cdots + SE^2_{study\ n}\right)}. \quad \text{(S1)}$$

Capture and recovery values were not available for all the gear-habitat combinations used to estimate the densities. To address these missing values, surrogate capture and recovery values were assigned for those gear-habitat combinations that did not have a literature-based efficiency value. Surrogate efficiencies were assigned based on the similarity of gear functionality or habitat type according to the following hierarchy. First, efficiency values should be the same for

gear type in a similar habitat (e.g., drop sampler in similar unstructured, non-vegetated habitat). If there was not a literature-based capture or recovery rate for that combination, values from a gear type with a similar functionality in the same habitat (e.g., drop sampler and throw trap function similarly in a marsh habitat) were used as surrogate values. If neither of the first two criteria was met, efficiency values from similar gears in similar habitats (e.g., drop net and lift net have similar functionality in structured habitats like SAV and marsh) were used as proxy values. If there was only one value for a gear type and it was not similar to any other gear type, then only capture and recovery rates available for that gear type in other habitats were used. Finally, if there was a caveat in the literature that justified the use of one efficiency value as a proxy, that value was used and the justification was noted.

Results

Capture-efficiency and recovery-efficiency values are presented in Tables S2 and S3, respectively. Average values from the literature are presented in black text in Tables S2 and S3. When a efficiency value was not available for a gear-habitat combination, a proxy based on the similarity of gear and/or habitat type was assigned. Proxy values are listed in red text.

References

Lorenz, J.J., C.C. McIvor, G.V.N. Powell, and P.C. Frederick. 1997. A drop net and removable walkway used to quantitatively sample fishes over wetland surfaces in the dwarf mangroves of the southern everglades. *Wetlands* 17(3): 346–359.

Rozas, L.P., and T.J. Minello. 1997. Estimating densities of small fishes and decapod crustaceans in shallow estuarine habitats: A review of sampling design with focus on gear selection. *Estuaries* 20(1): 199–213.

Supplement 2: Tables

Table S1 List of publications used for data extraction of gear-efficiency values.

#	Publications
1	Allen, D.M., S.K. Service, and M.V. Ogburn-Matthews. 1992. Factors influencing the collection efficiency of estuarine fishes. *Transactions of the American Fisheries Society* 121: 234–244.
2	Butcher, A., D. Mayer, D. Smallwood, and M. Johnston. 2005. A comparison of the relative efficiency of ring, fyke, fence nets and beam trawling for estimating key estuarine fishery populations. *Fisheries Research* 73(3): 311–321.
3	Camp, E.V., D.C. Gwinn, M.V. Lauretta, W.E. Pine, and T.K. Frazer. 2011. Use of recovery probabilities can improve sampling efficiency for throw traps in vegetated habitats. *Transactions of the American Fisheries Society* 140(1): 164–169.
4	Carlson, B.N., and C.R. Berry. 1990. Population size and economic value of aquatic bait species in palustrine wetlands of Eastern South Dakota. *Prairie Nature* 22(2): 119–128.
5	Castellanos, D.L. 1997. Nekton use of submerged aquatic vegetation, marsh, and shallow unvegetated bottom in a Louisiana tidal freshwater ecosystem. MS Thesis. University of Southwestern Louisiana.
6	Caudill, M.C. 2005. Nekton utilization of black mangrove (*Avicennia germinans*) and smooth cordgrass (*Spartina alterniflora*) sites in Southwestern Caminada Bay, Louisiana. Baton Rouge, Louisiana: MS Thesis. Louisiana State University.
7	Charles-Dominique, E. 1989. Catch efficiencies of purse and beach seines in Ivory Coast lagoons. *Fishery Bulletin* 87(4): 911–921.
8	Connolly, R.M. 1994. Comparison of fish catches from a buoyant pop net and a beach seine net in a shallow seagrass habitat. *Marine Ecology Progress Series* 109: 305–309.
9	Cotroneo, C., and D.J. Yozzo. 2010. W-fold throw trap: A folding, transportable 1-m^2 throw trap for use in densely vegetated aquatic habitats. *Journal of Freshwater Ecology* 25(1): 73–79.
10	Dorn, N.J., R. Urgelles, and J.C. Trexler. 2005. Evaluating active and passive sampling methods to quantify crayfish density in a freshwater wetland. *Journal of North American Benthological Society* 24(2): 346–356.
11	Freeman, B.J., H.S. Greening, and J.D. Oliver. 1984. Comparison of three methods for sampling fishes and macroinvertebrates in a vegetated freshwater wetland. *Journal of Freshwater Ecology* 2: 603–609.
12	Holland-Bartels, L.E., and M.R. Dewey. 1997. The influence of seine capture efficiency on fish abundance estimates in the upper Mississippi River. *Journal of Freshwater Ecology* 12(1): 101–111.
13	James-Piri, M.J., C.T. Roman, and J.L. Swanson. 2010. A method to quantitatively sample nekton in salt-marsh ditches and small tidal creeks. *Transactions of the American Fisheries Society* 139(2): 413–419.
14	Jordan, F., S. Coyne, and J.C. Trexler. 1997. Sampling fishes in vegetated habitats: Effects of habitat structure on sampling characteristic of the 1-m^2 throw trap. *Transactions of the American Fisheries Society* 126: 1012–1020.
15	Kjelson, M.A., and G.N. Johnson. 1974. Description and evaluation of a long-haul seine for sampling fish populations in offshore estuarine habitats. *Proceedings of the 28th Annual Conference of the Southeastern Association of Game Fish Commissioners*, 171–179.
16	Kneib, R.T. 1991. Flume weir for quantitative collection of nekton from vegetated intertidal habitats. *Marine Ecology Progress Series* 75: 29–38.
17	Kushlan, J.A. 1972. An ecological study of an alligator pond in the Big Cypress Swamp of Southern Florida. Coral Gables, Florida: MS Thesis, University of Miami.

Table S1 List of publications used for data extraction of gear-efficiency values.

#	Publications
18	Kushlan, J.A. 1981. Sampling characteristics of enclosure fish traps. *Transactions of the American Fisheries Society* 110: 557–562.
19	Larson, E.W., D.L. Johnson, and W.E. Lynch. 1986. A buoyant pop net for accurately sampling fish at artificial habitat structures. *Transactions of the American Fisheries Society* 115(2): 351–355.
20	Loesch, J.H., J. Bishop, A. Crowe, R. Kuckyr, and P. Wagner. 1976. Technique for estimating trawl efficiency in catching brown shrimp (*Penaeus aztecus*), Atlantic croaker (*Micropogon undulatus*) and spot (*Leiostomus xanthurus*). *Gulf Research Reports* 5: 29–33.
21	Lorenz, J.J., C.C. McIvor, G.V.N. Powell, and P.C. Frederick. 1997. A drop net and removable walkway used to quantitatively sample fishes over wetland surfaces in the dwarf mangroves of the southern everglades. *Wetlands* 17(3): 346–359.
22	Lyons, J. 1986. Capture efficiency of a beach seine for several freshwater fishes in a north-temperate lake. *North American Journal of Fisheries Management* 6: 288–289.
23	McIvor, C.C., and N.L. Silverman. 2010. Modifications to the bottomless lift net for sampling nekton in tidal mangrove forests. *Wetlands Ecology Management* 18: 627–635.
24	Parsley, M.J., D.E. Palmer, and R.W. Burkhardt. 1989. Variation in capture efficiency of a beach seine for small fishes. *North American Journal of Fisheries Management* 9: 239–244.
25	Pelicice, F.M., A.A. Agostinho, and S.M. Thomaz. 2005. Fish assemblages associated with Egeria in a tropical reservoir: investigating the effects of plant biomass and diel period. *Acta Oecologica* 27: 9–16.
26	Penczak, T., and K. O'Hara. 1983. Catch-effort efficiency using three small seine nets. *Fisheries Management* 14: 83–92.
27	Pierce, C.L., J.B. Rasmussen, and W.C. Leggett. 1990. Sampling littoral fish with a seine: Corrections for variable capture efficiency. *Canadian Journal of Fisheries and Aquatic Sciences* 47(4): 1004–1010.
28	Pihl, L., and R. Rosenberg. 1982. Production, abundance, and biomass of mobile epibenthic marine fauna in shallow waters, Western Sweden. *Journal of Experimental Marine Biology and Ecology* 57(2–3): 273–301.
29	Riha, M., J. Kubecka, T. Mrkvicka, M. Prchalova, M. Cech, V. Drastik, J. Frouzova, M. Hladik, E. Hohausova, O. Jarolim, T. Juza, M. Kratochvill, J. Peterka, M. Tuser, and M. Vasek. 2008. Dependence of beach seine net efficiency on net length and diel period. *Aquatic Living Resources* 21: 411–418.
30	Rozas, L.P. 1992. Bottomless lift net for quantitatively sampling nekton on intertidal marshes. *Marine Ecology Progress Series* 89: 287–292.
31	Rozas, L.P., and W.E. Odum. 1987. Fish and macrocrustacean use of submerged plant beds in tidal freshwater marsh creeks. *Marine Ecology Progress Series* 38: 101–108.
32	Rozas, L.P., and D.J. Reed. 1994. Comparing nekton assemblages of subtidal habitats in pipeline canals traversing brackish and saline marshes in coastal Louisiana. *Wetlands* 14(4): 262–275.
33	Sheridan, P.F. 1992. Comparative habitat utilization by estuarine macrofauna within the mangrove ecosystem of Rookery Bay, Florida. *Bulletin of Marine Science* 50(1): 21–39.
34	Shetter, D.S., and A.S. Hazzard 1939. Species composition by age groups and stability of fish populations in sections of three Michigan trout streams during the summer of 1937. *Transactions of the American Fisheries Society* 68(1): 281–302.
35	Steele, M.A., S.C. Schroeter, and H.M. Page. 2006. Sampling characteristics and biases of enclosure traps for sampling fishes in estuaries. *Estuaries and Coasts* 29(4): 630–638.
36	Stunz, G.W., T.J. Minello, and P.S. Levin. 2002. A comparison of early juvenile red drum densities among various habitat types in Galveston Bay, Texas. *Estuaries* 25: 76–85.

Table S1 List of publications used for data extraction of gear-efficiency values.

#	Publications
37	Stunz, G.W., T.J. Minello, and L.P. Rozas. L.P. 2010. Relative value of oyster reef as habitat for estuarine nekton in Galveston Bay, Texas. *Marine Ecology Progress Series* 406: 147–159.
38	Weinstein, M.P., and R.W. Davis. 1980. Collection efficiency of seine and rotenone samples from tidal creeks, Cape Fear River, North Carolina. *Estuaries* 3(2): 98–105.
39	Wenner, E., H.R. Beatty, and L.D. Coen. 1996. A method for quantitatively sampling nekton on intertidal oyster reefs. *J Shellfish Res* 15: 769–775.
40	Wenner, E.L., and H.R. Beatty. 1993. Utilization of shallow estuarine habitats in South Carolina, U.S.A., by postlarval and juvenile stages of Penaeus spp. (*Decapoda: Penaeidae*). *Journal of Crustacean Biology* 13(2): 280–295.
41	Wessel, M.R., and B.L. Winner. 2003. Using a modified purse seine to collect and monitor estuarine fishes. *Gulf and Caribbean Research* 15: 61–71.
42	Zimmerman, R.J., T.J. Minello, and G. Zamora. 1984. Selection of vegetated habitat by brown shrimp, *Penaeus aztecus*, in a Galveston Bay salt marsh. *Fishery Bulletin* 84(2): 325–336.

Table S2 Average capture efficiency values from literature and proxy capture-efficiency values (%). Only gear-habitat combinations captured in the database are included.

Gear type	NVB	SAV/seagrass	Marsh	Oyster reefs	Mangrove
Block net	70.0 (3.4)[a]				
Drop net		86.0 (2.6)[l]			
Throw trap	97.3 (16.3)[b]	75.7 (10.0)[m]	75.7 (10.0)[s]	75.7 (10.0)[m]	
Drop sampler	97.3 (16.3)[c]	94.0 (2.9)[n]	94.0 (2.9)[t]	94.0 (2.9)[n]	
Lift net	95.0 (1.7)[d]		86.0 (2.6)[l]	55.9 (10.2)[v]	86.0 (2.6)[l]
Cast net	95.0 (1.7)[d]				
Otter trawl	23.7 (8.0)[e]	23.7 (8.0)[o]			
Beam trawl	41.0 (3.6)[f]	41.0 (3.6)[p]			
Hand trawl	31.1 (6.1)[g]				
Seine	40.3 (5.5)[h]	48.9 (12.0)[q]			
Push trawl	40.3 (5.5)[i]			40.3 (5.5)i	
Epibenthic sled	70.5 (7.4)[j]	74.0 (6.9)[r]	74.0 (6.9)[u]	74.0 (6.9)[u]	
Substrate tray	70.5 (7.4)[k]			74.0 (6.9)[u]	

Key

Black text = capture efficiency averages from literature values.

Red text = assumptions, based on similarity of gear and habitat type.

Gray cell = no data available and no proxies assigned.

Source:

a. Butcher et al. (2005), N=2
b. Based on drop sampler in NVB
c. Pihl and Rosenberg (1982) and Zimmerman et al. (1984; comparative gear efficiencies), N=3
d. Based on purse seine in NVB, Butcher et al. (2005), N=2
e. Loesch et al. (1976) and Zimmerman et al. (1984; comparative gear efficiencies), N=4
f. Zimmerman et al. (1984) and Butcher et al. (2005), N=3
g. Based on otter trawl and beam trawl in NVB
h. Kjelson and Johnson (1974) and Zimmerman et al. (1984; comparative gear efficiencies), N=3
i. Based on seine in NVB
j. Stunz et al. (2002), N=1
k. Based on epibenthic sled in NVB
l. Based on drop net in mangrove, Lorenz et al. (1997), N=5
m. Based on throw trap in marsh
n. Based on drop sampler in marsh
o. Based on otter trawl in NVB
p. Based on beam trawl in NVB
q. Holland-Bartels and Dewey (1997) and Penczak and O'Hara (1983), N=80
r. Stunz et al. (2002), N=1
s. Kushlan (1981), Jordan et al. (1997), and Dorn et al. (2005), N=7
t. Zimmerman et al. (1984; comparative gear efficiencies), N=1
u. Based on epibenthic sled in SAV/seagrass
v. Wenner et al. (1996), N=4

Table S3 Average recovery efficiency values from literature and proxy recovery-efficiency values (%). Only gear-habitat combinations captured in the database are included.

Gear category	Gear type	NVB	SAV/ seagrass	Marsh	Oyster reefs	Mangrove
Enclosure	Block net	82.0 (9.3)[a]				
	Drop net		100 [e]			
	Throw trap	51.0 (8.5)[b]	91.3 (2.4)[f]	90.8 (5.2)[h]	44.0 (8.8)[k]	
	Drop sampler	92.8 (7.6)[c]	84.5 (12.2)[g]	91.7 (5.0)[i]	96.0 (2.5)[l]	
	Lift net	37.9 (7.0)[d]		63.0 (8.5)[j]	93.3 (3.4)[m]	62.5[n]
	Cast net	100[e]				
Towed net	Otter trawl	100 [e]	100 [e]			
	Beam trawl	100 [e]	100 [e]			
	Hand trawl	100 [e]				
	Seine	100 [e]	100 [e]			
	Push trawl	100 [e]			100 [e]	
	Epibenthic sled	100 [e]	100 [e]	100 [e]	100 [e]	
Passive	Substrate tray	100 [e]			100 [e]	

Key

Black text = recovery efficiency averages from literature values.

Red text = assumptions, based on similarity of gear and habitat type.

Blue text = assumed 100% efficiency for gear types without a secondary removal method.

Gray cell = no data available and no proxies assigned.

Source:

a. Based on block net in marsh, Jordan et al. (1997), N=4
b. Wenner and Beatty (1993), N=1
c. Zimmerman et al. (1984) and Sheridan (1992), N=2
d. Based on purse seine in NVB, Wessel and Winner (2003), N=1
e. Assumed 100% efficiency for gear types without a secondary removal method
f. Rozas and Odum (1987), Castellanos (1997), Pelicice et al. (2005), Steele et al. (2006), Cotroneo and Yozzo (2010), and Camp et al. (2011), N=19
g. Sheridan (1992) and Stunz et al. (2002), N=2
h. Carlson and Berry (1990), Wenner and Beatty (1993), Rozas and Reed (1994), Castellanos (1997), Jordan et al. (1997), and Dorn et al. (2005), N=17
i. Freeman et al. (1984), Zimmerman et al. (1984), and Sheridan (1992), N=3
j. Rozas (1992) and Caudill (2005), N=9
k. Wenner and Beatty (1993), N=1
l. Stunz et al. (2010), N=4
m. Stunz et al. (2002) and McIvor and Silverman (2010), N=3
n. Caudill (2005), N=2

Quantifying the Benefits of Estuarine Habitat Restoration in the Gulf of Mexico

- Proposal for thematic section in Estuaries and Coasts -

Organizers: Melissa Vernon Carle, Kristopher Benson

Submitted to:

Estuaries & Coasts Co-Editors-in-Chief: Paul Montagna and Charles Simenstad

Managing Editor: Taylor Bowen

May 23, 2017

This proposal includes: (1) a description of the proposed thematic section and how it fits within the aims and scope of *Estuaries and Coasts*; (2) a list of manuscripts by working title and author; (3) a timeline for manuscript submission, review, and final editorial decisions; and (4) names of organizers who will serve as guest editors.

1. *Description of theme and how it fits within the aims and scope of the journal*

Extensive restoration of estuarine habitats is expected to occur in the northern Gulf of Mexico region over the next several decades through funding from settlement agreements associated with the 2010 *Deepwater Horizon* oil spill. Restoration of estuarine habitat in the Gulf of Mexico should strive to not only replace the structural habitat lost as a result of the spill, but also to replace the full suite of lost ecological functions and services associated with those habitats to provide benefits to the wide array of estuarine resident and transient fauna injured by the spill. Quantification of the benefits associated with specific types of restoration projects can help managers compare projects and project designs, and assist with the selection of projects that maximize total benefits to the range of species and habitats injured by the spill. Understanding the rate of development of ecological functions and services within existing estuarine habitat restoration projects can also help with the selection of appropriate restoration targets and success criteria, and the design of restoration monitoring approaches.

Estuarine habitat restoration has been conducted for decades along the Gulf Coast through existing programs such as the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) program. However, many restoration projects are only monitored for a few years, with much monitoring focused on meeting specific construction targets (e.g. marsh elevation, volume of constructed oyster reefs) and the development of structural habitat features (e.g. vegetation percent cover). Larger, longer-term data sets are needed to fully understand the rate of development of restored habitats relative to reference habitats. In addition, data related to the

development of key habitat functions and services are necessary to improve understanding of how restored estuarine habitats compare with reference habitats.

This collection of papers provides insights into the quantification of benefits associated with estuarine habitat restoration projects in the northern Gulf of Mexico region. The authors of the papers included in this collection conducted systematic reviews of the existing literature on estuarine habitat restoration and utilization of estuarine habitats by species impacted by the *Deepwater Horizon* oil spill. Meta-analysis was used to synthesize existing data related to marsh vegetation and soil recovery; marsh resident fauna; and nekton abundance across marsh, oyster reef, submerged aquatic vegetation (SAV), and open water non-vegetated habitats. The authors used the results of the meta-analyses to develop quantitative relationships describing the recovery of key structural characteristics and ecological functions and services over time in restored coastal habitats relative to reference habitats. An approach is also presented to estimate the productivity of estuarine habitats based on the compiled nekton densities for specific habitats. Taken together, the syntheses presented in this series of papers provide a valuable resource for restoration managers planning and implementing coastal habitat restoration in the Gulf of Mexico. The synthesized datasets can be used to compare benefits associated with different types of restoration projects and serve as a reference for setting appropriate targets and performance criteria for restoration projects. The data compiled in this volume can also be applied to scale up the measured benefits of individual restoration projects to evaluate the longer-term, cumulative outcomes of restoration in the Gulf of Mexico.

In addition to synthesizing existing data on the development of habitat structure and ecological functions and services associated with estuarine habitat restoration, this theme section presents a method that can be used to quantify the benefits associated with a specific proposed marsh restoration project using the synthesized data sets presented in the other papers. Based on the Resource Equivalency Analysis (REA) approach developed to scale restoration needed to compensate for injuries within the context of Natural Resource Damage Assessment (NRDA) cases, this model provides a mechanism for quantifying total net project benefits that can be varied based on the marsh restoration technique employed, salinity regime, and geographic region. This marsh benefits model can be used to help compare the net benefits provided by potential future restoration projects; it also provides one approach that could be applied for scaling restoration needs for future NRDA cases involving injuries to marsh habitats in the northern Gulf of Mexico. An additional paper presents a similar model that can be used to quantify the benefits associated with the improvement of estuarine habitat quality through the removal of derelict crab traps, an important source of mortality to estuarine species in bays and estuaries throughout the Gulf of Mexico.

While this synthesis of existing data focuses specifically on the northern Gulf of Mexico region, the results presented in this theme section contribute to an overall better understanding of the ecological benefits of estuarine habitat restoration and can serve as a valuable reference for managers implementing restoration projects in other regions. Collectively, the papers in the

volume directly address the hypotheses that coastal habitat restoration projects eventually achieve structural and functional equivalence with reference habitats and that the rate of development of coastal habitat structure and function can be calculated and used to project the net benefits associated with a particular project over a given timeframe.

2. ***Tentative list of contributions and authors***

Quantifying the Benefits of Estuarine Habitat Restoration in the Gulf of Mexico: An Introduction to the Theme Section

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Extensive restoration of coastal and nearshore habitats is expected to occur in the northern Gulf of Mexico region over the next several decades, due in part to funding provided by settlements from the 2010 *Deepwater Horizon* oil spill. Understanding the ecological functions and services provided by restored estuarine habitats is critical to helping restoration managers plan effective restoration that maximizes benefits to the wide range of species injured by the spill. It will also help managers to set appropriate restoration targets and performance criteria and evaluate long-term restoration outcomes. To set the context for the body of work presented in this theme section, this introductory paper provides a comprehensive review of the existing literature on the outcomes of estuarine habitat restoration and existing methods used to estimate benefits of planned restoration projects within the context of compensatory restoration. The authors of the papers included in this theme section conducted systematic reviews of the existing literature on coastal and nearshore habitat restoration, focusing on development of habitat structural characteristics and utilization, recovery, and productivity of coastal resident and transient species known to have been impacted by the spill. They performed meta-analyses to synthesize existing data to develop quantitative relationships describing the development of ecological functions in restored coastal and nearshore habitats over time. In doing so, the authors also identify a number of important gaps in the existing datasets that should be the focus of future restoration monitoring efforts. Taken as a whole, the syntheses presented here provide valuable information for restoration managers planning and implementing coastal habitat restoration in the Gulf of Mexico and contribute to a better understanding of the overall ecological benefits of estuarine habitat restoration.

Using Meta-Analysis to Understand Recovery of Vegetation and Soils in Restored Wetlands in the Northern Gulf of Mexico

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The extent to which ecological structure and function of restored coastal wetlands in the northern Gulf of Mexico recover to conditions in reference (i.e., natural) wetlands has not been synthesized across the literature, but such a characterization would inform future restoration design and monitoring. We conducted a systematic literature review and meta-analysis of marsh creation and sediment addition sites in the northern Gulf of Mexico to evaluate whether vegetation and soil parameters at restored sites recover to reference levels and to estimate a recovery time for restored wetlands. We identified 1,342 candidate publications; of these, 25 studies were suitable for quantitative meta-analysis of vegetation and soil recovery, using paired comparisons of reference and restored sites (< 1 to 30+ years old). On average, root biomass and soil organic matter were 44% to 92% lower at restored sites < 15 years old compared to reference sites. Percent vegetation cover was 50% lower at restored sites compared to reference sites over the first five years of restoration; in contrast, aboveground biomass was 25% higher. Mean recovery trajectories for belowground biomass and productivity, vegetation cover, and soil parameters indicated that mean values for restored sites reached reference site conditions within 30 years following restoration; we also analyzed the slower recovery curve for the 20th percentile of site data. Evaluation of recovery rate following restoration depended on the response group and metric selected; these decisions of what parameters to monitor or incorporate into equivalency analyses will have a strong influence on the evaluation of project success.

Recovery of ecological function of salt marsh fauna following habitat restoration: Implications for restoration scaling in the northern Gulf of Mexico

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Recovery of the epifaunal gastropod periwinkle snail (*Littorina irrorata*) and a broad grouping of amphipod crustaceans (order *Amphipoda*) following salt marsh restoration in the northern Gulf of Mexico is investigated using meta-analysis. Recovery of the restored marsh system is defined in terms of the ecological function of these fauna and is quantified as the change in periwinkle biomass and amphipod density over time. Ecological function for each fauna is determined using a specific temporal recovery trajectory. The faunal recovery trajectories, which describe how quickly these resources in restored marshes return to conditions in reference systems, are developed using data extracted from published, unpublished, and grey literature

related to the structure and function of salt marsh habitat following marsh creation, marsh rehabilitation, or experimental treatments that closely mimic marsh restoration. Seven studies characterizing temporal changes in periwinkle population density following habitat restoration met the literature search criteria and four studies were identified for amphipods. For periwinkles, the results of the recovery trajectory analysis are used in conjunction with information regarding age class survivorship to estimate repopulation of the restored marsh through time. Because this species is long-lived (~10 years), ecological function is quantified as the addition of new biomass per unit area to the marsh surface in each year. New biomass is gained through juvenile recruitment (0-1 year old), the transition of juveniles to sub-adults (1-1.5 years old), and the transition of sub-adults to adults (>1.5 years old). Amphipods are shorter lived and turn over on annual time scales; thus, recovery of this faunal group is determined as the density in restored sites compared to reference marshes. The results of the analysis indicate progressive recovery of periwinkle function to equivalence with reference by year four in terms of density and year six with respect to annual biomass addition, while amphipods do not fully recover in the first 20 years following restoration. Although periwinkle function in terms of annual biomass addition reaches equivalence by year six, the development of a population structure characteristic of reference marshes would likely take longer because of the relatively long lifespan for this species. These faunal groups serve many critical marsh ecosystem functions including nutrient regeneration and represent key prey items for larger ecologically and economically important species. Therefore, developing an understanding of how important lower trophic organisms recover following habitat restoration has broader ecosystem implications. In addition, the approach described here to quantify the temporal change in ecological function of a specific resource can also be applied generally in a natural resource damage assessment (NRDA) context to provide insight into the benefits of habitat restoration, for example, of salt marshes in the northern Gulf of Mexico.

Meta-analysis of nekton utilization of coastal habitats in the northern GOM

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Estuarine habitats in the northern Gulf of Mexico (GOM) provide important habitat for many ecologically and commercially important fish and crustacean species (i.e., nekton), but patterns of nekton abundance and community assemblages across habitat types and seasons have not been described region-wide. We conducted a systematic literature search and meta-analysis to evaluate nekton densities across several estuarine habitat types, including marsh, oyster reefs, submerged aquatic vegetation (SAV), and open-water non-vegetated bottom (NVB). The overall objective of our study was to evaluate spatial and seasonal patterns of nekton utilization associated with different estuarine habitats. This study also presents a meta-analytical approach that can be applied to aggregate densities from different studies and gear types to understand key research questions. Higher nekton densities were associated with structured estuarine habitats

(i.e., marsh, oyster reefs, SAV) and with the structure itself of those habitats (e.g., marsh edges, interior areas) than with open-water NVB habitats. Marsh and SAV community assemblages were relatively similar to each other but different from those associated with open-water NVB and oyster habitats. Densities of recreationally and commercially important crustacean and fish species were highest in saline marshes, thus demonstrating the importance of these habitats in the northern GOM. Considering the vital importance of estuarine habitats for producing and maintaining healthy populations of numerous ecologically and economically valuable species to the northern GOM, this study provides valuable insights to inform resource management decisions and effective coastal restoration.

Meta-Analysis of Nekton Recovery Following Marsh Restoration in the Northern Gulf of Mexico

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In recent years, federal and state authorities have focused on restoration of coastal wetland habitats in the northern Gulf of Mexico (GOM) to combat regional land loss and habitat degradation. To date, ecological research on marsh recovery following restoration typically has been focused on individual sites, studies, and restoration types. To investigate broader regional responses, we conducted a meta-analysis of nekton densities measured at restored marsh sites in the northern GOM compared to reference (i.e., natural) sites to describe general patterns of nekton recovery following restoration that could inform future restoration planning and to identify areas of further research. Overall, total nekton densities at restored sites were generally lower than those at reference sites, even a decade or more following restoration in some cases. We found a wide variation in restored versus reference densities among individual fish and crustacean species; densities of most crustaceans (e.g., mud crab Panopeidae spp., penaeid shrimp Penaeidae spp., grass shrimp Palaemonidae spp.) and some fish species (e.g., gobies Gobiidae spp.) were generally lower at restored sites, while densities of most fish, as well as blue crabs, at restored sites approached or exceeded densities at reference sites. Nekton densities – and constituent crustacean densities – appeared to increase with the age at restored sites, and approached equivalence with densities at reference sites in some cases within a decade. Our findings show that even carefully planned marsh restoration often is not sufficient to compensate for nekton production that is lost when natural sites are disturbed or damaged, particularly in the earlier years of post-restoration when baseline ecological functions (e.g., development of organic matter, colonization by benthic infauna) must develop to successfully support healthy nekton communities. We also emphasize the importance of looking at other functional metrics of ecological equivalency, such as size, growth, community composition, and trophic support, which could be important indictors of overall ecosystem fisheries support. Based on our meta-analysis, we recommend that key abiotic and biotic factors be considered in restoration planning,

implementation, and monitoring to ensure achievement of coastal restoration goals in the northern GOM.

Estimating Fish and Invertebrate Secondary Productivity in Shallow Coastal Systems: Implications for Coastal Restoration and Management

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Coastal habitat restoration projects are implemented for a variety of purposes, including the replacement of impacted or injured habitat, shoreline stabilization and the protection of coastal communities, and the provision of habitat for wildlife, including protected species, resident and migratory birds, and marsh resident and transient aquatic and marine organisms. The goals of individual coastal habitat restoration projects should inform their design and implementation as well as the monitoring of completed projects and criteria for the evaluation of project success. A key metric to gauge the habitat value of shallow coastal systems and develop appropriate management policies is secondary productivity. Measurements of secondary productivity are particularly important for fish that recruit to shallow coastal systems and is highly relevant for coastal management policies, including planning and support of restoration efforts. For instance, quantification of secondary productivity associated to specific habitats may provide quantifiable targets for the restoration of these habitats. Unfortunately, secondary productivity is not easy to measure and estimates of this metric are limited in the literature. Here, we present a protocol to derive estimates of secondary productivity for fish and invertebrates that inhabit shallow coastal systems in the Gulf of Mexico. We borrow from established methods to build a cohesive construct for secondary productivity estimates. We also show how to quantify the uncertainty of those estimates. We focus on fish species that recruit to shallow coastal systems and migrate offshore as adults, and on invertebrates that reside in the systems throughout their life spans. We also discuss how the calculations can be applied to other purposes, such as estimates of fish biomass export as juveniles leave the shallows. This work contributes to our understanding and

assessment of the habitat value of shallow coastal systems as well as the development of well-informed management and restoration strategies.

Quantification of coastal marsh restoration benefits in the northern Gulf of Mexico: Modeling the development of marsh ecological functions

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Extensive salt marsh restoration is expected in the northern Gulf of Mexico over the next several decades, funded in part by settlements from the 2010 Deepwater Horizon oil spill. An understanding of the ecological functioning of restored marshes over time is integral to setting appropriate restoration targets and performance criteria and to understanding how much restoration is needed to achieve desired benefits. We present a method for quantifying anticipated ecological benefits associated with marsh restoration projects, particularly marsh creation, in the northern Gulf of Mexico. Using salt marsh vegetation (percent cover, aboveground biomass, and belowground biomass), periwinkle snails, and amphipods as representative ecological components, we modeled anticipated ecological functioning over time and quantified total net project benefits for a hypothetical marsh creation project in Barataria Bay, Louisiana. We applied a resource equivalency analysis approach with rigorous development of input values that included mining the scientific literature, Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) data, and other sources. We also demonstrate how model inputs can be varied to accommodate different marsh restoration techniques, salinity regimes, and geographic regions. Another potential application for this model is restoration scaling in a natural resource damage assessment (NRDA) context for future marsh injuries in the northern Gulf of Mexico region

Estimating the Benefits of Crab Trap Removal Programs to Restore Fish and Water Column Invertebrates in the Gulf of Mexico

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Ghost fishing in derelict blue crab traps is ubiquitous and causes incidental mortality of crab and fish species which can be reduced by programs that remove derelict crab traps. In an effort to scale the benefits of such removal programs, in the context of restoring the Gulf of Mexico after

the Deepwater Horizon oil spill, this paper calculates the ecological benefits of trap removal by estimating the extent of derelict blue crab traps across 28 Gulf of Mexico waterbodies and combining these estimates with Gulf-specific crab and finfish mortality rates due to ghost fishing. The highest numbers and densities of traps are found in Louisiana, with estimates ranging up to 203,000 derelict traps across the state and up to 41 traps per square kilometer in areas such as Terrebonne Bay. Mortality rates are estimated at 26 crabs per trap per year and 8 fish per trap per year. The results of this analysis indicate a Gulf-wide removal program targeting 10 percent of derelict traps over the course of five years would lead to a combined benefit of more than 691,000 kilograms of crabs and fish prevented from mortality in ghost fishing traps. These results emphasize the importance of ongoing derelict trap removal programs. Future work could apply the model developed in this analysis to assess additional benefits of trap removal programs, such as fewer entanglements of marine mammals and sea turtles, improved aesthetics, and increases in harvestable catch that result in economic benefits for fishers and communities. Lastly, this model could be utilized by fishery managers to calculate the benefits of other management options designed to decrease the extent and impact of derelict fishing gear.

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ON THE EXACT VARIANCE OF PRODUCTS*

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A simple exact formula for the variance of the product of two random variables, say, x and y, is given as a function of the means and central product-moments of x and y. The usual approximate variance formula for xy is compared with this exact formula; e.g., we note, in the special case where x and y are independent, that the "variance" computed by the approximate formula is less than the exact variance, and that the accuracy of the approximation depends on the sum of the reciprocals of the squared coefficients of variation of x and y. The case where x and y need not be independent is also studied, and exact variance formulas are presented for several different "product estimates." (The usefulness of exact formulas becomes apparent when the variances of these estimates are compared.) When x and y are independent, simple unbiased estimates of these exact variances are suggested; in the more general case, consistent estimates are presented.

1. INTRODUCTION AND SUMMARY

THE usual formula, which has appeared in the statistical literature, for the variance of the product of two independent random variables is an approximation (see, for example, Yates [3, p. 198]). In this literature, it has also been suggested that this approximate formula for the variance is satisfactory only if the coefficients of variation of the two random variables are both relatively small. In the present note, we shall present a simple exact formula for this variance, which does not depend on any assumptions concerning the magnitudes of the coefficients of variation. The relative accuracy of the usual approximate formula for this variance will be computed. It will be seen that the "variance" obtained using the approximate formula is less than the exact variance, and that the approximation may be satisfactory in some cases where one or both of the coefficients of variation are relatively small. A simple unbiased estimate of the exact variance will also be presented. The exact formula for the variance will then be used to compute the relative efficiency of two different kinds of estimates of a parameter that is in fact equal to the product of two other parameters. (The reader will note that the usual approximate variance formula could not be used to compute correctly the relative efficiency of these two estimates. In fact, if the approximate variance formula had been applied, rather than the exact formula, an erroneous conclusion regarding the relative efficiency of these estimates might have been obtained.) This exact formula will also be generalized to obtain an exact formula for the variance of the product of three (or more) independent random variables. Finally, the situation where the random variables need not be independent will be investigated, and exact

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I am indebted to R. L. Ashenhurst, H. L. Jones and R. Summers for some helpful comments. Formula (18) was obtained independently by Professor Jones using a somewhat different method from that presented in the present note.

variance formulas will be presented in this case along with consistent estimates of these variances.

The method of obtaining the exact variance formulas, which are presented here, is quite simple. This method can be generalized to obtain exact formulas for any of the central moments of the product of two or more random variables. These formulas could also be derived from general formulas relating product-moments about the origin to central product-moments (see, for example, Kendall and Stuart [1, p. 82] and Tschuprow [2]), but an additional set of calculations would then be required in order to modify the formulas obtained for the product-moments about the origin so that relatively simple formulas could be obtained for the central moments of the product. The present paper presents a more direct method of proof. To the best of my knowledge, the simple exact formulas presented in this paper are new. (It seems surprising that they should not have appeared in print before this.)

There are many situations where the variance of the product of two random variables is of interest (e.g., where an estimate is computed as a product of two other estimates), so that it will not be necessary to describe these situations in any detail in the present note.

2. THE CASE WHERE THE RANDOM VARIABLES ARE INDEPENDENT

Let x and y be two independent random variables. Let us denote the expected value of x by $E(x)=X$, the variance of x by $V(x)$, and the square of the coefficient of variation of x by $V(x)/X^2=G(x)$. A similar notation will be used for the random variable y. (For the sake of simplicity, we shall assume here that $E(x)=X$ and $E(y)=Y$ differ from zero, although some of the results presented here do not require this assumption.) Since

$$xy - XY = XY[(\delta x + 1)(\delta y + 1) - 1] = XY[\delta y + \delta x + \delta x \delta y] \tag{1}$$

where $\delta x=(x-X)/X$ and $\delta y=(y-Y)/Y$, we have that the variance $V(xy)$ of the product xy is equal to

$$\begin{aligned} V(xy) &= E\{(xy - XY)^2\} = (XY)^2[G(y) + G(x) + G(x)G(y)] \\ &= X^2V(y) + Y^2V(x) + V(x)V(y). \end{aligned} \tag{2}$$

The usual approximate formula, which has appeared in the literature, is

$$\tilde{V}(xy) = X^2V(y) + Y^2V(x) = (XY)^2[G(y) + G(x)]. \tag{3}$$

Thus, the relative inaccuracy of the approximation $\tilde{V}(xy)$ is

$$\begin{aligned} R &= [V(xy) - \tilde{V}(xy)]/V(xy) = G(x)G(y)/[G(x) + G(y) + G(x)G(y)] \\ &= 1/[A + 1], \end{aligned} \tag{4}$$

where $A=G^{-1}(x)+G^{-1}(y)$. From (4) we see that, if either $G(x)$ or $G(y)$ is quite small, then A will be relatively large, and the relative inaccuracy will be small. Thus, the approximate formula may be satisfactory even in some cases where only one of the two coefficients is small, contrary to what has usually been suggested in the literature.

We shall now present an unbiased estimate of the variance $V(xy)$. Since $E(x^2)-X^2=V(x)$, we have that

$$\begin{aligned} v(xy) &= [x^2 - v(x)]v(y) + [y^2 - v(y)]v(x) + v(x)v(y) \\ &= x^2v(y) + y^2v(x) - v(x)v(y) \end{aligned} \tag{5}$$

is an unbiased estimate of $V(xy)$, where $v(x)$ is an unbiased estimate of $V(x)$ and $v(y)$ is an unbiased estimate of $V(y)$. It is interesting to note that, while $V(x)V(y)$ is added to the usual approximate formula $\tilde{V}(xy)=X^2V(y)+Y^2V(x)$ to obtain the exact formula for $V(xy)$, the quantity $v(x)v(y)$ is subtracted from the estimate $\bar{v}(xy)=x^2v(y)+y^2v(x)$ to obtain the unbiased estimate $v(xy)$ of $V(xy)$.

Let us now consider the situation where a sample of x's and an independent sample of y's are obtained, and where the sample sizes are $n(x)$ and $n(y)$, respectively. Let $\bar{x}$ and $\bar{y}$ be the sample means of the x's and y's, respectively, and let $s^2(x)$ and $s^2(y)$ be the usual unbiased estimates of $V(x)$ and $V(y)$, respectively. Then $\bar{x}\bar{y}$ will be an unbiased estimate of XY whose variance is

$$\begin{aligned} V(\bar{x}\bar{y}) &= X^2V(\bar{y}) + Y^2V(\bar{x}) + V(\bar{x})V(\bar{y}) \\ &= X^2\frac{V(y)}{n(y)} + Y^2\frac{V(x)}{n(x)} + \frac{V(x)V(y)}{n(x)n(y)}\,. \end{aligned} \tag{6}$$

An unbiased estimate of $V(\bar{x}\bar{y})$ will be

$$\begin{aligned} v(\bar{x}\bar{y}) &= \bar{x}^2v(\bar{y}) + \bar{y}^2v(\bar{x}) - v(\bar{x})v(\bar{y}) \\ &= \bar{x}^2\frac{s^2(y)}{n(y)} + \bar{y}^2\frac{s^2(y)}{n(x)} - \frac{s^2(x)s^2(y)}{n(x)n(y)}\,. \end{aligned} \tag{7}$$

When $n(x)=n(y)=n$, the variance $V(\bar{x}\bar{y})$ becomes simply

$$V(\bar{x}\bar{y}) = [X^2V(y) + Y^2V(x) + V(x)V(y)/n]/n, \tag{8}$$

and the unbiased estimate of $V(\bar{x}\bar{y})$ becomes

$$v(\bar{x}\bar{y}) = [\bar{x}^2s^2(y) + \bar{y}^2s^2(x) - s^2(x)s^2(y)/n]/n. \tag{9}$$

If a sample of n paired observations (x_i, y_i) is obtained $(i=1, 2, \cdots, n)$, then

$$\sum_{i=1}^{n} x_iy_i/n = z$$

is also an unbiased estimate of XY in the special case where x and y are independent random variables. In this case, the variance of z is

$$V(z) = V(xy)/n = [X^2V(y) + Y^2V(x) + V(x)V(y)]/n, \tag{10}$$

and the relative efficiency of the estimate z as compared with the estimate $\bar{x}\bar{y}$ is

$$V(\bar{x}\bar{y})/V(z) = \frac{[X^2V(y) + Y^2V(x) + V(x)V(y)/n]}{[X^2V(y) + Y^2V(x) + V(x)V(y)]}, \tag{11}$$

which approaches

$$\tilde{V}(xy)/V(xy) = [G(y) + G(x)]/[G(y) + G(x) + G(y)G(x)] \tag{12}$$

as $n \to \infty$. Thus, the estimate z is less efficient than the estimate $\bar{y}\bar{x}$ in this case, and the relative decrease in the variance of $\bar{x}\bar{y}$ as compared with the variance of z approaches ($n \to \infty$)

$$1 - [\tilde{V}(xy)/V(xy)] = R = 1/[A + 1], \tag{13}$$

where $A = G^{-1}(x) + G^{-1}(y)$ as earlier herein. Thus, we see that, when x and y are independent, the effect of using the usual approximate formula $\tilde{V}(xy)$ rather than the exact formula $V(xy)$ is comparable to the effect of using the statistic z rather than $\bar{x}\bar{y}$ as an estimate of the product XY of the parameters X and Y (when $n \to \infty$).

The preceding results can be generalized to obtain exact formulas in the situation where the product of three (or more) independent random variables is of interest. For example, let the three random variables be x, y, and z, where X, Y, and Z are their respective means, $V(x)$, $V(y)$, $V(z)$ are their respective variances, and $G(x)$, $G(y)$, $G(z)$ are their respective squared coefficients of variation. Since

$$\begin{aligned} xyz - XYZ &= XYZ[(\delta x + 1)(\delta y + 1)(\delta z + 1) - 1] \\ &= XYZ[\delta x + \delta y + \delta z + \delta x\delta y + \delta x\delta z + \delta y\delta z + \delta x\delta y\delta z], \end{aligned} \tag{14}$$

where the δ's are defined as earlier herein, we have that the variance $V(xyz)$ of the product xyz is equal to

$$\begin{aligned} V(xyz) &= E\{(xyz - XYZ)^2\} \\ &= (XYZ)^2[G(x) + G(y) + G(z) + G(x)G(y) + G(x)G(z) + G(y)G(z) \\ &\qquad + G(x)G(y)G(z)]. \end{aligned} \tag{15}$$

An approximate formula for this variance (comparable to the usual approximate formula for the variance of the product of two independent random variables) would be

$$\tilde{V}(xyz) = (XYZ)^2[G(x) + G(y) + G(z)], \tag{16}$$

which we now see will be satisfactory only if the term

$$(XYZ)^2[G(x)G(y) + G(x)G(z) + G(y)G(z) + G(x)G(y)G(z)]$$

can be neglected. Formula (15) is a generalization of (2), while formula (16) is a generalization of (3).

3. THE CASE WHERE THE RANDOM VARIABLES NEED NOT BE INDEPENDENT

Let x and y be two random variables (not necessarily independent). Let us denote the expected value of xy by $E(xy) = M_{11}$ and the covariance between δx and δy by $E\{\delta x\delta y\} = D_{11}$. We also write $E\{(\delta x)^i(\delta y)^j\} = D_{ij}$ and $E\{(\Delta x)^i(\Delta y)^j\} = E_{ij}$, where $\Delta x = x - X$ and $\Delta y = y - Y$. Since

$$\begin{aligned} xy - M_{11} &= XY[(\delta x + 1)(\delta y + 1) - B_{11}], \\ &= XY[\delta x + \delta y + \delta x\delta y + F_{11}], \end{aligned} \tag{17}$$

where $B_{11}=M_{11}/(XY)$ and $F_{11}=1-B_{11}=-D_{11}$, we see that the variance $V(xy)$ of the product xy is equal to

$$\begin{aligned} V(xy) &= (XY)^2[G(y)+G(x)+2D_{11}+2D_{12}+2D_{21}+D_{22}-D_{11}^2] \\ &= X^2V(y)+Y^2V(x)+2XYE_{11}+2XE_{12}+2YE_{21}+E_{22}-E_{11}^2, \end{aligned} \tag{18}$$

where $E_{22}-E_{11}^2=V(\Delta x\Delta y)$ is the variance of $\Delta x\Delta y$. The usual approximate formula for $V(xy)$ is

$$\tilde{V}(xy) = X^2V(y)+Y^2V(x)+2XYE_{11}, \tag{19}$$

which we now see will be satisfactory only if the term $2X_{12}+2YE_{21}+V(\Delta x\Delta y)$ can be neglected.

If a sample of n paired observations (x_i, y_i) are obtained $(i=1, 2, \cdots, n)$, then

$$\sum_{i=1}^{n} x_iy_i/n = z$$

is an unbiased estimate of M_{11} and $\bar{x}\bar{y}$ is a consistent estimate of XY. It is easy to see that the expected value of $\bar{x}\bar{y}$ is $E\{\bar{x}\bar{y}\}=XY(1-1/n)+M_{11}/n$ $=XY+E_{11}/n$, so that the statistic $(\bar{x}\bar{y}n-z)/(n-1)=w$ is an unbiased estimate of XY. The variance of z is

$$\begin{aligned} V(z) &= \frac{V(xy)}{n} \\ &= [X^2V(y)+Y^2V(x)+2XYE_{11}+2XE_{12}+2YE_{21}+V(\Delta x\Delta y)]/n, \end{aligned} \tag{20}$$

while the variance of $\bar{x}\bar{y}$ is

$$\begin{aligned} V(\bar{x}\bar{y}) = \Bigg[& X^2V(y)+Y^2V(x)+2XYE_{11}+2X\frac{E_{12}}{n}+2Y\frac{E_{21}}{n} \\ & +\frac{V(x)V(y)}{n}+\frac{\mathrm{Cov}[(\Delta x)^2,(\Delta y)^2]-E_{11}^2}{n^2}\Bigg]\Big/ n, \end{aligned} \tag{21}$$

where Cov $[(\Delta x)^2, (\Delta y)^2]=E_{22}-V(x)V(y)$ is the covariance between the random variables $(\Delta x)^2$ and $(\Delta y)^2$. The mean squared error of $\bar{x}\bar{y}$ as an estimate of XY is

$$MSE(\bar{x}\bar{y}) = V(\bar{x}\bar{y})+(E_{11}/n)^2. \tag{22}$$

Since the estimate w of XY is asymptotically equivalent to $\bar{x}\bar{y}$, the variance $V(w)$ of w can be simply approximated using the fact that the limiting value $(n\rightarrow\infty)$ of $nV(w)$ is equal to the limiting value of $nV(\bar{x}\bar{y})$ and $nMSE(\bar{x}\bar{y})$. Thus, we have that

$$V(w) \cong [X^2V(y)+Y^2V(x)+2XYE_{11}]/n = \tilde{V}(xy)/n. \tag{23}$$

Consistent estimates of $V(z)$, $V(\bar{x}\bar{y})$, $MSE(\bar{x}\bar{y})$, and $V(w)$ can be obtained by replacing the various population moments by the corresponding sample mo-

ments (which will be consistent estimates of the corresponding population moments) in equations (20), (21), (22), and (23), respectively.

The ratio of $V(\bar{x}\bar{y})$ to $V(z)$ approaches

$$\tilde{V}(xy)/V(xy) = \frac{[X^2V(y) + Y^2V(x) + 2XYE_{11}]}{[X^2V(y) + Y^2V(x) + 2XYE_{11} + 2XE_{12} + 2YE_{21} + V(\Delta x \Delta y)]} \tag{24}$$

as $n \to \infty$. We also see that $\tilde{V}(xy)/V(xy)$ is the limiting value for $MSE(\bar{x}\bar{y})/V(z)$ and $V(w)/V(z)$. Thus, the effect of using the usual approximate formula $\tilde{V}(xy)$ rather than the exact formula $V(xy)$ is comparable to the relative difference between the variance of the estimate z of M_{11} and the variance of the estimate w (or $\bar{x}\bar{y}$) of XY (when $n \to \infty$).

The preceding results can be generalized to deal with the situation where the product of three (or more) random variables is of interest (where these random variables need not necessarily be independent). The method of obtaining these results can also be generalized in order to obtain exact formulas for any of the central moments of the product of two or more random variables. These results can also be directly generalized to deal with situations where the ratio of random variables or the product of powers of random variables are of interest.

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