

USE OF *SPARTINA ALTERNIFLORA* LOISEL. (GRAMINEAE) SALT MARSHES BY JUVENILE FISHES: EFFECTS OF THE PRESENCE OF *MAGALLANA GIGAS* (THUNBERG, 1793) ON DISTRIBUTION PATTERNS

©2026 Lucas M. Molina (<https://orcid.org/0000-0002-0574-2367>)^{a, b}, Leonel Luppi^b, Daniel Barrio^{a, b}

^a Universidad Nacional de Río Negro, Viedma, Río Negro, 8500, Argentina

^b CIT Río Negro (UNRN-CONICET), Viedma, Río Negro, 8500, Argentina

Received January 07, 2026. Revised May 28, 2026. Accepted August 19, 2026

Salt marshes are ecologically important ecosystems that provide high biodiversity and key ecosystem services but are increasingly threatened by global wetland loss driven by climate change, sea-level rise, and human activities. Invasive species such as the Pacific oyster *Magallana gigas* can function as autogenic ecosystem engineers, which modify habitat structure and associated biological communities. In the Bahía Blanca Estuary, Argentina, we evaluated the effects of oyster presence on fish assemblages in vegetated *Spartina alterniflora* marshes and adjacent non-vegetated habitats. Fish were sampled using gillnets during nine tidal cycles, and changes in prey availability and sediment characteristics were also assessed. Vegetated areas showed higher fish abundance, greater species diversity, and larger body sizes than non-vegetated oyster-dominated areas. Oyster invasion was additionally associated with shifts in benthic food resources and sediment properties. These results demonstrate that *M. gigas* significantly alters fish assemblage structure, underscoring the need to incorporate biological invasions into salt marsh conservation and management strategies.

Keywords: salt marshes; Bahía Blanca Estuary; *Magallana gigas*; fish; *Spartina alterniflora*.

DOI: 10.35885/1996-1499-19-3-262-267

Full text of the paper is published in Russian Journal of Biological Invasions.

REFERENCES

- Adam, P. (2019). Salt marsh restoration. In Coastal wetlands (pp. 817-861). Elsevier.
- Akin, S., Buhan, E., Winemiller, K.O., & Yilmaz, H. (2005). Fish assemblage structure of Koycegiz Lagoon Estuary, Turkey: spatial and temporal distribution patterns in relation to environmental variation. *Estuarine, Coastal and Shelf Science*, 64, 671-684.
- Anderson, M.J., & Millar, R.B. (2004). Spatial variation and effects of habitat on temperate reef fish assemblages in northeastern New Zealand. *Journal of Experimental Marine Biology and Ecology*, 305(2), 191-221.
- Baker, R., Taylor, M.D., Able, K.W., Beck, M.W., Cebrian, J., Colombano, D.D., & Staver, L.W. (2020). Fisheries rely on threatened salt marshes. *Science*, 370(6517), 670-671.
- Battini, N., Giachetti, C.B., Castro, K.L., Bortolus, A., & Schwindt, E. (2021). Predator-prey interactions as key drivers for the invasion success of a potentially neurotoxic sea slug. *Biological Invasions*, 23(4), 1207-1229.
- Beck, M.W., Heck, K.L., Able, K.W., Childers, D.L., Eggleston, D.B., Gillanders, B.M., & Weinstein, M.P. (2001). The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates. *Bioscience*, 51(8), 633-641.
- Bell, J.D., & Pollard, D. (1989). Ecology of fish assemblages and fisheries associated with seagrasses. In A.W.D. Larkum, A.J. McComb, & S.A. Shepherd (Eds.), *Biology of seagrasses* (pp. 565-609). Elsevier, Amsterdam.
- Bertness, M.D. (1991). Zonation of *Spartina patens* and *Spartina alterniflora* in New England salt marsh. *Ecology*, 72(1), 138-148.
- Bertness, M.D. (1999). The ecology of Atlantic shorelines (vol. 417). Sunderland: Sinauer Associates.
- Bertness, M.D., & Coverdale, T.C. (2013). An invasive species facilitates the recovery of salt marsh ecosystems on Cape Cod. *Ecology*, 94(9), 1937-1943.
- Bertness, M.D., & Ellison, A.M. (1987). Determinants of pattern in a New England salt marsh plant community. *Ecological Monographs*, 57(2), 129-147.
- Bertness, M.D., & Hacker, S.D. (1994). Physical stress and positive associations among marsh plants. *The American Naturalist*, 144(3), 363-372.
- Boesch, D.F., & Turner, R.E. (1984). Dependence of fishery species on salt marshes: the role of food and refuge. *Estuaries*, 7(4), 460-468.
- Bortolus, A., Schwindt, E., & Iribarne, O. (2002). Positive plant-animal interactions in the high marsh of an Argentinean coastal lagoon. *Ecology*, 83(3), 733-742.

- Braga, A.C., Camacho, C., Marques, A., Gago-Martínez, A., Pacheco, M., & Costa, P.R. (2018). Combined effects of warming and acidification on accumulation and elimination dynamics of paralytic shellfish toxins in mussels *Mytilus galloprovincialis*. *Environmental Research*, 164, 647-654.
- Brown, A.C., & McLachlan, A. (2010). *The ecology of sandy shores*. Elsevier.
- Brucet, S., Boix, D., López-Flores, R., Badosa, A., Moreno-Amich, R., & Quintana, X.D. (2005). Zooplankton structure and dynamics in permanent and temporary Mediterranean salt marshes: taxon-based and size-based approaches. *Archiv für Hydrobiologie*, 162(4), 535-556.
- Burrows, M.T., Schoeman, D.S., Buckley, L.B., Moore, P., Poloczanska, E.S., Brander, K.M., & Richardson, A.J. (2011). The pace of shifting climate in marine and terrestrial ecosystems. *Science*, 334(6056), 652-655.
- Buscher, K., Ehinger, E., Gupta, P., Pramod, A. B., Wolf, D., Tweet, G., & Ley, K. (2017). Natural variation of macrophage activation as disease-relevant phenotype predictive of inflammation and cancer survival. *Nature Communications*, 8(1), 16041.
- Callaway, R.M. (1995). Positive interactions among plants. *The Botanical Review*, 61, 306-349.
- Camaño, A. (2012). *Humedales Costeros: Aportes científicos a su gestión sustentable*. Ediciones UC.
- Carlton, J.T. (2021). Patterns of transoceanic marine biological invasions in the Pacific Ocean. In *A Natural History of the Hawaiian Islands* (pp. 504-518). University of Hawaii Press.
- Carlton, J.T., & Cohen, A.N. (2003). Episodic global dispersal in shallow water marine organisms: the case history of the European shore crabs *Carcinus maenas* and *C. aestuarii*. *Journal of Biogeography*, 30(12), 1809-1820.
- Carlton, J.T., & Geller, J.B. (1993). Ecological roulette: the global transport of nonindigenous marine organisms. *Science*, 261(5117), 78-82.
- Castel, J., Labourg, P.J., Escaravage, V., Auby, I., & Garcia, M.E. (1989). Influence of seagrass beds and oyster parks on the abundance and biomass patterns of meio- and macrobenthos in tidal flats. *Estuarine, Coastal and Shelf Science*, 28(1), 71-85.
- Cech, J.J., Mitchell, S.J., Castleberry, D.T., & McEnroe, M. (1990). Distribution of California stream fishes: influence of environmental temperature and hypoxia. *Environmental Biology of Fishes*, 29, 95-105.
- Chao, L.N., & Musick, J.A. (1977). Life-history, feeding-habits, and functional-morphology of juvenile Sciaenid fishes in York River Estuary, Virginia. *Fishery Bulletin*, 75(4), 657.
- Chen, L., Song, Y., Li, S., Zhang, L., Zou, C., & Yu, D. (2012). The role of WRKY transcription factors in plant abiotic stresses. *Biochimica et Biophysica Acta (BBA)-Gene Regulatory Mechanisms*, 1819(2), 120-128.
- Cohen, A.N., & Carlton, J.T. (1998). Accelerating invasion rate in a highly invaded estuary. *Science*, 279(5350), 555-558.
- Colden, A.M., Fall, K.A., Cartwright, G.M., & Friedrichs, C.T. (2016). Sediment suspension and deposition across restored oyster reefs of varying orientation to flow: implications for restoration. *Estuaries and Coasts*, 39, 1435-1448.
- Connolly, R. (1994b). Removal of seagrass canopy: effects on small fish and their prey. *Journal of Experimental Marine Biology and Ecology*, 184, 99-110.
- Connolly, R.M. (1994a). A comparison of fish assemblages from seagrass and unvegetated areas of a southern Australian estuary. *Marine and Freshwater Research*, 45(6), 1033-1044.
- Connolly, R.M., Dalton, A., & Bass, D.A. (1997). Fish use of an inundated saltmarsh flat in a temperate Australian estuary. *Australian Journal of Ecology*, 22, 222-226.
- Connor, E.F., & McCoy, E.D. (1979). The statistics and biology of the species-area relationship. *The American Naturalist*, 113(6), 791-833.
- Cousseau, M.B., Marchesi, M.C., Díaz de Astarloa, J.M., & González-Castro, M. (2011). The ichthyologic relationship between the Mar Chiquita coastal lagoon and the adjacent sea. *Historia Natural*, 1, 85-100.
- Crosby, S.C., Sax, D.F., Palmer, M.E., Booth, H.S., Deegan, L.A., Bertness, M.D., & Leslie, H.M. (2016). Salt marsh persistence is threatened by predicted sea-level rise. *Estuarine, Coastal and Shelf Science*, 181, 93-99.
- Cyrus, D.P., & Blaber, S.J.M. (1987a). The influence of turbidity on juvenile marine fishes in estuaries. Part 1. Field studies at Lake St. Lucia on the southeastern coast of Africa. *Journal of Experimental Marine Biology and Ecology*, 109(1), 53-70.
- Cyrus, D.P., & Blaber, S.J.M. (1987b). The influence of turbidity on juvenile marine fishes in estuaries. Part 2. Laboratory studies, comparisons with field data and conclusions. *Journal of Experimental Marine Biology and Ecology*, 109(1), 71-91.
- da Cunha Lana, P., & Guiss, C. (1992). Macrofauna-plant-biomass interactions in a euhaline salt marsh in Paranaguá Bay (SE Brazil). *Marine Ecology Progress Series*, 80, 57-64.
- Darrigran, G., Agudo-Padrón, I., Baez, P., Belz, C., Cardoso, F., Carranza, A., & Damborenea, C. (2020). Non-native mollusks throughout South America: emergent patterns in an understudied continent. *Biological Invasions*, 22, 853-871.
- Davy, A.J., Brown, M.J., Mossman, H.L., & Grant, A. (2011). Colonization of a newly developing salt marsh: disentangling independent effects of elevation and redox potential on halophytes. *Journal of Ecology*, 99(6), 1350-1357.
- De Groot, S.J. (1971). On the interrelationships between morphology of the alimentary tract, food and feeding behaviour in flatfishes (Pisces: Pleuronectiformes). *Netherlands Journal of Sea Research*, 5(2), 121-196.
- Diederich, S., Nehls, G.J.E.E., Van Beusekom, J.E., & Reise, K. (2005). Introduced Pacific oysters (*Crassostrea gigas*) in the northern Wadden Sea: invasion accelerated by warm summers? *Helgoland Marine Research*, 59(2), 97-106.
- Dolmer, P., Holm, M.W., Strand, A., *et al.* (2014). The invasive Pacific oyster, *Crassostrea gigas*, in Scandinavian coastal waters. 70 p.
- Downes, S., & Shine, R. (1998). Heat, safety or solitude? Using habitat selection experiments to identify a lizard's priorities. *Animal Behaviour*, 55(5), 1387-1396.

- Edgar, G.J., & Shaw, C. (1995). The production and trophic ecology of shallow-water fish assemblages in southern Australia II. *Journal of Experimental Marine Biology and Ecology*, 194(1), 83-106.
- Eleftheriou, A. (Ed.). (2013). *Methods for the study of marine benthos*. John Wiley & Sons.
- Escapa, M., Perillo, G.M., & Iribarne, O. (2015). Biogeomorphically driven salt pan formation in *Sarcocornia*-dominated salt-marshes. *Geomorphology*, 228, 147-157.
- Faria, J., Prestes, A.C.L., Moreu, I., Cacabelos, E., & Martins, G.M. (2022). Dramatic changes in the structure of shallow-water marine benthic communities following the invasion by *Rugulopteryx okamurae* (Dictyotales, Ochrophyta) in Azores (NE Atlantic). *Marine Pollution Bulletin*, 175, 113358.
- Fei, S., Phillips, J., & Shouse, M. (2014). Biogeomorphic impacts of invasive species. *Annual Review of Ecology, Evolution, and Systematics*, 45, 69-87.
- Fernandez, T.V., Milazzo, M., Badalamenti, F., & D'Anna, G. (2005). Comparison of the fish assemblages associated with *Posidonia oceanica* after the partial loss and consequent fragmentation of the meadow. *Estuarine, Coastal and Shelf Science*, 65(4), 645-653.
- Figuerola, D.E. (2019). Clave de peces marinos del Atlántico Sudoccidental, entre los 33°S y 56°S. *Publicación del INIDEP. Mar del Plata*.
- Gedan, K.B., Crain, C.M., & Bertness, M.D. (2009). Small-mammal herbivore control of secondary succession in New England tidal marshes. *Ecology*, 90(2), 430-440.
- Giangiobbe, A., & Sánchez, F. (1993). Alimentación de la saraca (*Brevoortia aurea*). *Frente Marítimo*, 14, 71-80.
- Gilby, B.L., Weinstein, M.P., Baker, R., Cebrian, J., Alford, S.B., Chelsky, A., & Ziegler, S.L. (2021). Human actions alter tidal marsh seascapes and the provision of ecosystem services. *Estuaries and Coasts*, 44, 1628-1636.
- Grabowski, J.H., Hughes, A.R., Kimbro, D.L., & Dolan, M. A. (2005). How habitat setting influences restored oyster reef communities. *Ecology*, 86(7), 1926-1935.
- Gray, V.R., & Ríos, M.P. (1996). Salinidad y el nivel del agua como factores en la distribución de la vegetación en la ciénaga del NW de Campeche, México. *Acta Botánica Mexicana*, 34, 53-61.
- Grenouillet, G., Pont, D., & Seip, K.L. (2002). Abundance and species richness as a function of food resources and vegetation structure: juvenile fish assemblages in rivers. *Ecography*, 25(6), 641-650.
- Hammer, Ø., & Harper, D.A. (2001). Past: paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, 4(1), 1.
- Harding, J.M. (2001). Temporal variation and patchiness of zooplankton around a restored oyster reef. *Estuaries*, 24, 453-466.
- Harwell, H.D., Posey, M.H., & Alphin, T.D. (2011). Landscape aspects of oyster reefs: effects of fragmentation on habitat utilization. *Journal of Experimental Marine Biology and Ecology*, 409(1-2), 30-41.
- Heck, K.L., & Thoman, T.A. (1984). The nursery role of seagrass meadows in the upper and lower reaches of the Chesapeake Bay. *Estuaries*, 7, 70-92.
- Heck, K.L., Hays, G., & Orth, R.J. (2003). Critical evaluation of the nursery role hypothesis for seagrass meadows. *Marine Ecology Progress Series*, 253, 123-136.
- Herbert, R.J., Humphreys, J., Davies, C.J., Roberts, C., Fletcher, S., & Crowe, T.P. (2016). Ecological impacts of non-native Pacific oysters (*Crassostrea gigas*) and management measures for protected areas in Europe. *Biodiversity and Conservation*, 25, 2835-2865.
- Hines, J.M., Hungerford, H.R., & Tomera, A.N. (1987). Analysis and synthesis of research on responsible environmental behaviour: A meta-analysis. *The Journal of Environmental Education*, 18(2), 1-8.
- Holbrook, S.J., & Schmitt, R.J. (1988). The combined effects of predation risk and food reward on patch selection. *Ecology*, 69(1), 125-134.
- Hollingsworth, A., & Connolly, R.M. (2006). Feeding by fish visiting inundated subtropical saltmarsh. *Journal of Experimental Marine Biology and Ecology*, 336(1), 88-98.
- Holmer, M., Gribsholt, B., & Kristensen, E. (2002). Effects of sea level rise on growth of *Spartina anglica* and oxygen dynamics in rhizosphere and salt marsh sediments. *Marine Ecology Progress Series*, 225, 197-204.
- Hosack, G.R., Dumbauld, B.R., Ruesink, J.L., & Armstrong, D.A. (2006). Habitat associations of estuarine species: comparisons of intertidal mudflat, seagrass (*Zostera marina*), and oyster (*Crassostrea gigas*) habitats. *Estuaries and Coasts*, 29, 1150-1160.
- Houser, D.S., & Allen, D.M. (1996). Zooplankton dynamics in an intertidal salt-marsh basin. *Estuaries*, 19, 659-673.
- Houttuijn Bloemendaal, L.J., FitzGerald, D.M., Hughes, Z.J., Novak, A.B., & Georgiou, I.Y. (2023). Reevaluating the wave power-salt marsh retreat relationship. *Scientific Reports*, 13(1), 2884.
- Hovel, K.A., Fonseca, M.S., Myer, D.L., Kenworthy, W.J., & Whitfield, P.E. (2002). Effects of seagrass landscape structure, structural complexity and hydrodynamic regime on macrofaunal densities in North Carolina seagrass beds. *Marine Ecology Progress Series*, 243, 11-24.
- Hozbor, N.M., & García de la Rosa, S.B. (2000). Alimentación de juveniles de corvina rubia (*Micropogonias furnieri*) en la laguna costera Mar Chiquita (Buenos Aires, Argentina).
- Hughes, Z., Farron, S.J., & FitzGerald, D.M. (2022). Differential Headward Erosion of Marsh Tidal Creeks: Ecological and Physical Causes. Available at SSRN 4112818.
- IPCC. (2007). Cuarto informe de evaluación del Grupo Intergubernamental de Expertos sobre el Cambio Climático (IPCC).
- Isacch, J.P., Costa, C.S.B., Rodríguez-Gallego, L., Conde, D., Escapa, M., Gagliardini, D.A., & Iribarne, O.O. (2006). Distribution of saltmarsh plant communities associated with environmental factors along a latitudinal gradient on the south-west Atlantic Coast. *Journal of Biogeography*, 33, 888-900.
- Jackson, J.B. (1985). *Discovering the vernacular landscape*. Kingsford, M., & Battershill, C. (1998). *Studying temperate marine environments: A handbook for ecologists*. Canterbury University Press.

- Kneib, R.T. (1997). The role of tidal marshes in the ecology of estuarine nekton. *Oceanography and Marine Biology: An Annual Review*, 35, 163-220.
- Lefeuvre, J.C., Bouchard, V., Feunteun, E., Grare, S., Lafaille, P., & Radureau, A. (2000). European salt marshes diversity and functioning: the case study of the Mont Saint-Michel bay, France. *Wetlands Ecology and Management*, 8, 147-161.
- Lenihan, H.S., & Peterson, C.H. (1998). How habitat degradation through fishery disturbance enhances impacts of hypoxia on oyster reefs. *Ecological Applications*, 8(1), 128-140.
- Leonard, L.A., & Luther, M.E. (1995). Flow hydrodynamics in tidal marsh canopies. *Limnology and Oceanography*, 40(8), 1474-1484.
- Levin, S.A. (1994). Patchiness in marine and terrestrial systems: from individuals to populations. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, 343(1303), 99-103.
- Lewis, D.B., & Eby, L.A. (2002). Spatially heterogeneous refugia and predation risk in intertidal salt marshes. *Oikos*, 96(1), 119-129.
- Little, C. (2000). *The biology of soft shores and estuaries*. Oxford University Press.
- Lortie, C.J., & Callaway, R.M. (2006). Re-analysis of meta-analysis: support for the stress-gradient hypothesis. *Journal of Ecology*, 94(1), 7-16.
- Lough, R.G., Valentine, P.C., Potter, D.C., Auditore, P.J., Bolz, G.R., Neilson, J.D., & Perry, R.I. (1989). Ecology and distribution of juvenile cod and haddock in relation to sediment type and bottom currents on eastern Georges Bank. *Marine Ecology Progress Series*, 1-12.
- MacArthur, R.H. (1965). Patterns of species diversity. *Biological Reviews*, 40(4), 510-533.
- Mack, R.N., Simberloff, D., Mark Lonsdale, W., Evans, H., Clout, M., & Bazzaz, F.A. (2000). Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications*, 10(3), 689-710.
- Martinetto, P., Ribeiro, P., & Iribarne, O. (2007). Changes in distribution and abundance of juvenile fishes in intertidal soft sediment areas dominated by the burrowing crab *Chasmagnathus granulatus*. *Marine and Freshwater Research*, 58, 194-203.
- Massicotte, P., Bertolo, A., Brodeur, P., Hudon, C., Mingelbier, M., & Magnan, P. (2015). Influence of the aquatic vegetation landscape on larval fish abundance. *Journal of Great Lakes Research*, 41(3), 873-880.
- Mendoza-Carranza, M., & Vieira, J. (2008). Whitemouth croaker *Micropogonias furnieri* (Desmarest, 1823) feeding strategies across four southern Brazilian estuaries. *Aquatic Ecology*, 42, 83-93.
- Méndez Casariego, A., Schwindt, E., & Iribarne, O. (2004). Evidence of habitat structure-generated bottleneck in the recruitment process of the SW Atlantic crab *Cyrtograpsus angulatus*. *Marine Biology*, 145, 259-264.
- Michalet, R., & Pugnaire, F.I. (2016). Facilitation in communities. *Functional Ecology*, 30(1), 3-9.
- Minello, T.J., Able, K.W., Weinstein, M.P., & Hays, C.G. (2003). Salt marshes as nurseries for nekton: testing hypotheses on density, growth and survival through meta-analysis. *Marine Ecology Progress Series*, 246, 39-59.
- Mobberley, D.G. (1953). *Taxonomy and distribution of the genus Spartina*. Iowa State University.
- Molina, L.M. (2013). El rol de la biota en los procesos de estabilización-desestabilización de sedimentos estuariales. PhD thesis. Universidad Nacional del Sur. Argentina, 289 pp.
- Molina, L.M., & López Gappa, J.J. (2016). Biogenic structures of a non-native bryozoan increase colonization by invasive species and cause *Spartina alterniflora* die-off. *Marine & Freshwater Invasive Species: Ecology, Impact, and Management (MFIS)*. Buenos Aires.
- Molina, L.M., Gonzales Dubox, C., & Lopez Carzola, A. (2023a). Southernmost occurrence of *Gobiosoma hemigymnum* (Eigenmann & Eigenmann, 1888) on salt marshes of the Bahía Blanca estuary, Argentina: an unusual finding. *Journal of the Marine Biological Association of the United Kingdom*, 103, e31, 1-6.
- Molina, L.M., Nicolás León, & Barrio, D.E. (2019). Relative impacts of eutrophication and consumers on shoreline stability in a salt marsh. *Congreso COLACMAR*.
- Molina, L.M., Valiñas, M.S., Pratolongo, P.D., Elias, R., & Perillo, G.M. (2017). Effect of Whitemouth Croaker (*Micropogonias furnieri*, Pisces) on the stability of the sediment of salt marshes – an issue to be resolved. *Estuaries and Coasts*, 40, 1795-1807.
- Molina, M.A., Luppi, L., Luna, M., Barrio, D., & Molina, L.M. (2023b). Efecto de *Magallana gigas* en el uso de marismas por peces en marismas. *Reunión Argentina de Ecología*. Bariloche, Argentina.
- Morgan, P.A., Burdick, D.M., & Short, F.T. (2009). The functions and values of fringing salt marshes in northern New England, USA. *Estuaries and Coasts*, 32, 483-495.
- Mouritsen, K.N., & Jensen, K.T. (1992). Choice of microhabitat in tactile foraging dunlins *Calidris alpina*: the importance of sediment penetrability. *Marine Ecology Progress Series*, 85, 1-8.
- Neill, W.H., & Magnuson, J.J. (1974). Distributional ecology and behavioral thermoregulation of fishes in relation to heated effluent from a power plant at Lake Monona, Wisconsin. *Transactions of the American Fisheries Society*, 103(4), 663-710.
- Nomann, B.E., & Pennings, S.C. (1998). Fiddler crab-vegetation interactions in hypersaline habitats. *Journal of Experimental Marine Biology and Ecology*, 225(1), 53-68.
- Orensanz, J.M., Schwindt, E., Pastorino, G., Bortolus, A., Casas, G., Darrigran, G., & Vallarino, E.A. (2002). No longer the pristine confines of the world ocean: a survey of exotic marine species in the southwestern Atlantic. *Biological Invasions*, 4, 115-143.
- Orth, R.J. (1992). A perspective on plant-animal interactions in seagrasses: physical and biological determinants influencing plant and animal abundance. In D. M. John, S. J. Hawkins, & J. H. Price (Eds.), *Plant-Animal Interactions in the Marine Benthos*. Clarendon Press, Oxford.
- Orth, R.J., & van Montfrans, J. (1990). Utilization of marsh and seagrass habitats by early stages of *Callinectes sapidus*: a latitudinal perspective. *Bulletin of Marine Science*, 46(1), 126-144.

- Padilla, D.K. (2010). Context-dependent impacts of a non-native ecosystem engineer, the Pacific oyster *Crassostrea gigas*. *Integrative and Comparative Biology*, 50(2), 213-225.
- Paterson, A.W., & Whitfield, A.K. (2000). Do shallow-water habitats function as refugia for juvenile fishes? *Estuarine, Coastal and Shelf Science*, 51(3), 359-364.
- Pereyra, P.J., de la Barra, P., Saad, J.F., Gastaldi, M., Arcángel, A.E., Rodríguez, E.A., & Narvarte, M. (2021). Unraveling facilitation among introduced species, a mechanistic approach. *Biological Invasions*, 23(11), 3483-3496.
- Perillo, G. M. E., and M. E. Sequeira (1989). Geomorphologic and sediment transport characteristics of the middle reach of the Bahía Blanca estuary (Argentina). *Journal of Geophysical Research*, 94(C10), 14351-14362.
- Perillo, G.M., & Iribarne, O.O. (2003). Processes of tidal channel development in salt and freshwater marshes. *Earth Surface Processes and Landforms*, 28(13), 1473-1482.
- Piccolo, M. C., & Perillo, G. M. E. (1990). Physical characteristics of the Bahía Blanca estuary (Argentina). *Estuarine, Coastal and Shelf Science*, 31, 303-317.
- Piccolo, M.C., & Perillo, G.M.E. (2000). Geomorfología de los estuarios: una vision diferente.
- Piovan, M.J., Zapperi, G.M., & Pratolongo, P.D. (2014). Seed germination of *Atriplex undulata* under saline and alkaline conditions. *Seed Science and Technology*, 42(2), 286-292.
- Platell, M.E., & Freewater, P. (2009). Importance of salt-marsh to fish species of a large south-eastern Australian estuary during a spring tide cycle. *Marine and Freshwater Research*, 60(9), 936-941.
- Poloczanska, E.S., Brown, C.J., Sydeman, W.J., Kiessling, W., Schoeman, D.S., Moore, P.J., & Richardson, A.J. (2013). Global imprint of climate change on marine life. *Nature Climate Change*, 3(10), 919-925.
- Ren, X., Zhang, X., Yan, C., & Gozgor, G. (2022). Climate policy uncertainty and firm-level total factor productivity: Evidence from China. *Energy Economics*, 113, 10620.
- Ríos, I., Bouza, P.J., Bortolus, A., & del Pilar Alvarez, M. (2018). Soil-geomorphology relationships and landscape evolution in a southwestern Atlantic tidal salt marsh in Patagonia, Argentina. *Journal of South American Earth Sciences*, 84, 385-398.
- Rodríguez, L.F. (2006). Can invasive species facilitate native species? Evidence of how, when, and why these impacts occur. *Biological Invasions*, 8, 927-939.
- Schwaner, C., Barbosa, M., Schwemmer, T.G., Pales Espinosa, E., & Allam, B. (2023). Increased food resources help eastern oyster mitigate the negative impacts of coastal acidification. *Animals*, 13(7), 1161.
- Schwindt, E., & Bortolus, A. (2017). Aquatic invasion biology research in South America: Geographic patterns, advances and perspectives. *Aquatic Ecosystem Health & Management*, 20(4), 322-333.
- Schwindt, E., Gappa, J.L., Raffo, M.P., Tatián, M., Bortolus, A., Orensanz, J.M., & Sueiro, M.C. (2014). Marine fouling invasions in ports of Patagonia (Argentina) with implications for legislation and monitoring programs. *Marine Environmental Research*, 99, 60-68.
- Sih, A. (1992). Prey uncertainty and the balancing of anti-predator and feeding needs. *The American Naturalist*, 139(5), 1052-1069.
- Silliman, B.R., & Bertness, M.D. (2002). A trophic cascade regulates salt marsh primary production. *Proceedings of the National Academy of Sciences*, 99(16), 10500-10505.
- Smith, L.D., & Coull, B.C. (1987). Juvenile spot (Pisces) and grass shrimp predation on meiobenthos in muddy and sandy substrata. *Journal of Experimental Marine Biology and Ecology*, 105(2-3), 123-136.
- Sogard, S.M., & Able, K.W. (1991). A comparison of eelgrass, sea lettuce macroalgae, and marsh creeks as habitats for epibenthic fishes and decapods. *Estuarine, Coastal and Shelf Science*, 33(5), 501-519.
- Stunz, G.W., & Minello, T.J. (2001). Habitat-related predation on juvenile wild-caught and hatchery-reared red drum *Sciaenops ocellatus* (Linnaeus). *Journal of Experimental Marine Biology and Ecology*, 260(1), 13-25.
- Thomas, B.E., & Connolly, R.M. (2001). Fish use of subtropical saltmarshes in Queensland, Australia: relationships with vegetation, water depth and distance onto the marsh. *Marine Ecology Progress Series*, 209, 275-288.
- Thunberg, C.P. (1793). Tekning och Beskrifning på en stor Ostronsort ifrån Japan. *Kongliga Vetenskaps Akademiens Nya Handlingar*, 14(4-6), 140-142.
- Traut, B.H. (2005). The role of coastal ecotones: a case study of the salt marsh/upland transition zone in California. *Journal of Ecology*, 279-290.
- Troost, K. (2010). Causes and effects of a highly successful marine invasion: case-study of the introduced Pacific oyster *Crassostrea gigas* in continental NW European estuaries. *Journal of Sea Research*, 64(3), 145-165.
- Underwood, A.J. (1992). Beyond BACI: the detection of environmental impacts on populations in the real, but variable, world. *Journal of Experimental Marine Biology and Ecology*, 161(2), 145-178.
- Underwood, A.J. (1997). *Experiments in ecology: their logical design and interpretation using analysis of variance*. Cambridge University Press.
- Valiela, I., & Valiela, I. (1995). *Marine ecological processes* (vol. 686). New York: Springer.
- Valiñas, M.S., Molina, L.M., Addino, M., Montemayor, D.I., Acha, E.M., & Iribarne, O.O. (2012). Biotic and environmental factors affect Southwest Atlantic saltmarsh use by juvenile fishes.
- Van der Wal, D., & Pye, K. (2004). Patterns, rates and possible causes of saltmarsh erosion in the Greater Thames area (UK). *Geomorphology*, 61(3-4), 373-391.
- Weisburd, R.S., & Laws, E.A. (1990). Free water productivity measurements in leaky mariculture ponds. *Aquacultural Engineering*, 9(6), 377-403.
- Whitfield, A.K. (1999). Ichthyofaunal assemblages in estuaries: a South African case study. *Reviews in Fish Biology and Fisheries*, 9, 151-186.
- Whitman, E.R., & Reidenbach, M.A. (2012). Benthic flow environments affect recruitment of *Crassostrea virginica* larvae to an intertidal oyster reef. *Marine Ecology Progress Series*, 463, 177-191.
- Wilson, C A., Hughes, Z.J., & FitzGerald, D.M. (2022). Causal relationships among sea level rise, marsh crab

- activity, and salt marsh geomorphology. *Proceedings of the National Academy of Sciences*, 119(9), e2111535119.
- Wolanski, E., Martinez, J.A., & Richmond, R.H. (2009). Quantifying the impact of watershed urbanization on a coral reef: Maunalua Bay, Hawaii. *Estuarine, Coastal and Shelf Science*, 84(2), 259-268.
- Zar, J.H. (1999). *Biostatistical analysis*. Englewood Cliff: Prentice-Hall.