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Chapter 5.

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A SALTY DIVIDE WITHIN ASLO?

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Aquatic scientists have long realized that understanding whole ecosystems requires integrating a broad set of ideas and diverse perspectives – what we now call interdisciplinary science. The mission of the Association for the Sciences of Limnology and Oceanography (ASLO) is to "foster a diverse, international scientific community that creates, integrates and communicates knowledge across the full spectrum of aquatic sciences…" But how integrative is ASLO even between the two disciplines that have organized since 1947 under this single society? As the fields of oceanography and limnology grow in both number of practitioners and their importance to society in addressing pressing global environmental issues (e.g., acidification, eutrophication, hypoxia, over-exploitation, habitat and biodiversity loss), are we realizing the maximum benefits from cross-fertilization of concepts and methods? Has there been a temporal change in the degree to which these two disciplines share ideas? Alfred Redfield, the first ASLO president, noted in the Announcement to the first issue of the journal *Limnology and Oceanography* (*L&O*) that "… the differences between fresh and salt water (are) trivial, when compared to the common principles with which limnologists and oceanographers alike are concerned" (Redfield 1956). Accordingly, *L&O* served to "increase our understanding of the aquatic environment." In other words, the similarities should far outweigh the differences and each group has much to learn from the other.

As society faces increasingly complex problems and as science develops to address this complexity, innovative programs at universities, government agencies and professional societies are being developed that encourage collaborative efforts and interdisciplinary training of future scientists. At the 2010 NSF-sponsored Ecological Dissertations in Aquatic Sciences (Eco-DAS) symposium, a group of recent and soon-to-be PhDs from a variety of disciplines under the broad heading of "Aquatic Sciences" became interested in exploring the perception, and potential reality, that ASLO is made up of two distinct groups of scientists that are becoming increasingly *less* interdisciplinary with respect to the disciplines of limnology and oceanography. Is there a "salty-divide" in ASLO that impedes interactions between the two disciplines? The initial motivation for these questions came from the recognition that, as a group of early career limnolo-

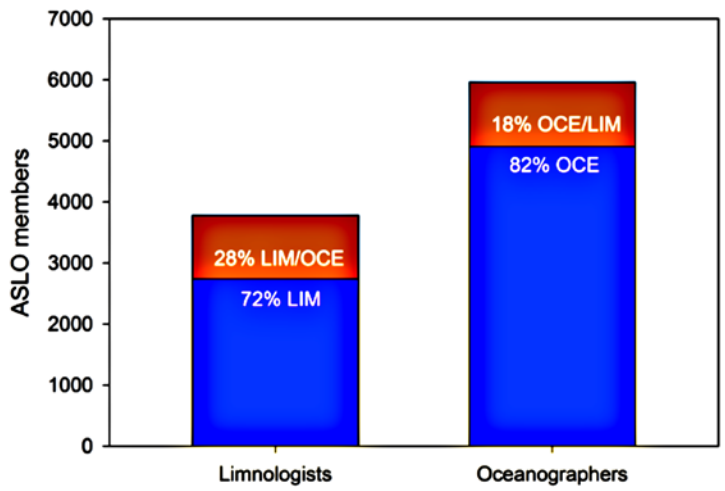

Fig 1. Patterns by which ASLO members classify their individual fields of study. Members self-identified as oceanographers (OCE), limnologists (LIM), or both listing their primary field first.

Journal	Journal Specialty	N articles	5-yr Impact Factor	Search Span
Freshwater Biology	Freshwater	100	3.78	1990-2009
Journal of Great Lakes Research	Freshwater	100	1.79	1990-2009
Fundamental and Applied Limnology (Archiv fur Hydrobiologie)	Freshwater	100	1.14	1990-2009
Progress in Oceanography	Marine	100	4.21	1990-2009
Deep Sea Research II	Marine	100	1.97	1993-2009
Marine Ecology Progress Series	Marine	100	2.63	1990-2009
Limnology and Oceanography	Both marine and freshwater	101 (each discipline)	4.00	1956-2009

Table 1. Descriptions of journals used in cross-citation study. Impact factors were collected from individual journal websites based on publication by Thomson Reuters and reflect calculations for 2005-2009. Articles were chosen within the search span in a stratified-random fashion (see Methods).

gists and oceanographers, we each had something to offer our counterparts in the other discipline—e.g., statistical tools, theory, methodologies—and concurrently, recognized the many ways we could benefit through increased interaction with the other discipline. Indeed, the idea of interacting with other aquatic scientists with different backgrounds at a critical stage in one's career was the premise for holding the symposium in the first place, and we wondered if limnologists and oceanographers at large also viewed work by the other discipline as a source of new ideas, methodologies and knowledge.

From this perspective we developed a set of questions and testable hypotheses that might shed light on how these disciplines interact both in terms of how multi-disciplinary practitioners view themselves as well as where investigators look for insight (e.g., journals outside their primary field). Broadly, are oceanographers more, less or equally likely as limnologists to cross-train or cross-pollinate ideas? More specifically, can disparities be detected within ASLO and the scientific literature? To address the former, we used an anonymous version of the ASLO member database to assess how members self-identify, and presumably practice, within four categories: oceanography (OCE), limnology (LIM), OCE/LIM or LIM/OCE, with the last two categories reflecting primary/secondary identification. For the latter question, we undertook a literature review to examine cross-citation between freshwater and marine studies among freshwater focused journals, marine focused journals and an interdisciplinary journal, *Limnology and Oceanography*.

We focused on self-identification in the ASLO database to gauge whether members trained or practiced in multiple disciplines. The majority of ASLO members self-identified as solely within one field of study (Figure 1). Approximately equal numbers of individuals from each primary field also listed the other field (~1050 members from each). However, oceanographers outnumbered limnologists by 3:2 in ASLO membership, thus limnologists were significantly more likely to list both fields (28% vs. 18%; $p < 0.001$). The pattern was nearly identical when considering only members that classify themselves as biological in sub-discipline (60% of total membership). Members listing chemical as their primary sub-discipline were more likely to list a secondary field of study, with the proportion higher for limnologists than oceanographers (37% LIM/OCE vs. 23% OCE/LIM $p<0.01$); this difference was slightly larger for members listing physical as their primary sub-discipline (32% LIM/OCE vs. 16% OCE/LIM, $p<0.05$). Therefore, while the vast majority of scientists within ASLO's membership identify with a single discipline, limnologists were more likely than oceanographers to consider themselves members of both disciplines.

To assess rates of cross-citation between disciplines, we examined 600 papers from marine and freshwater specialty journals (~1990 to present) and > 5 decade time series from *Limnology and Oceanography* (Table 1). To constrain our search, we focused on trends among ecological papers only. Specialty journals were chosen based on similar impact factors (Menge et al., 2009) and the requirement that they regularly published ecological studies. Of the 100 papers examined within each disciplinary journal, authors of papers specific to freshwater journals were significantly more likely to have cited marine journals than the reverse ($P < 0.001$; Figure 2). Authors of freshwater focused papers cited at least one marine focused journal 38% of the time. In contrast, marine focused papers with a freshwater journal citation occurred on average just 4% of the time. Of the 100 papers examined from *Deep Sea Research II* (~5000 individual citations), none were from freshwater journals. These patterns were generally consistent within *L&O* also. Across the publication record, authors of papers from the marine environment were significantly less likely to cite freshwater journals than the reverse ($P < 0.001$; Figure 2). There was temporal variation within *L&O*, however (Figure 3). Notably, the cross citation disparity was

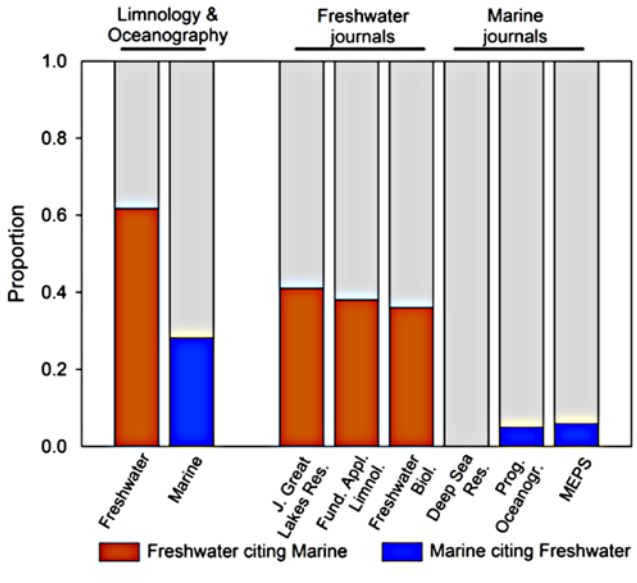

Figure 2. Patterns in journal article cross-citation between freshwater and marine ecosystems within the journal *Limnology and Oceanography* and in three disciplinary journals specific to each environment. Papers were selected randomly, stratified over the publication record of the journal. See Table 1 for the full names of journals.

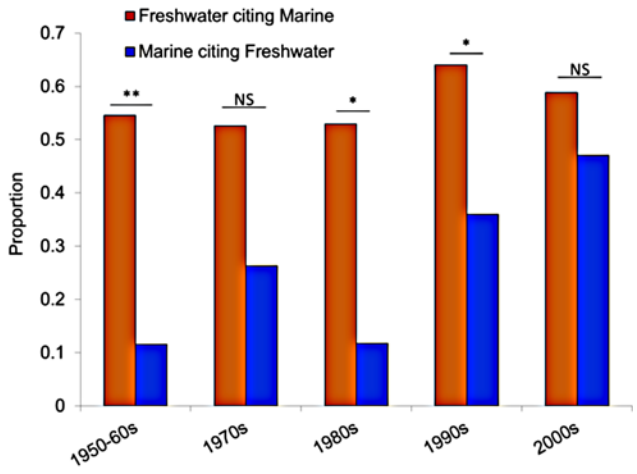

Figure 3. Proportion of habitat-specific papers within *Limnology and Oceanography* that cross-cite. Articles were binned into time-periods: 1956-69, 1970-79, 1980-89, 1990-99 and 2000-2009. Log-likelihood and p-values were calculated, where NS= not significant, *= $p<0.05$, **=$p<0.01$.

largest during the 1980s but it has all but disappeared in the last 10 years.

Is there a scientific basis to the salty divide or is it one of training and tradition? In the past decade, literature meta-analyses have been useful in illuminating the known and unknown biases of natural scientists (e.g., Stergiou and Browman, 2005; Menge et al., 2009). Here we have quantified potential epistemological differences between limnologists and oceanographers, both in terms of self-identification and literature cited. Focusing primarily on cross-citation, there are several potential reasons that may underlie the results: 1) inherent journal bias, 2) realized system differences beyond the salinity gradient, and 3) cultural differences associated with institutions, training, and historical legacies.

We focused our study at the specialty journal level to gauge whether practitioners were actively seeking information outside of their dominant discipline. In general ecology journals, the habitat–specific publication rate tends to closely track editorial expertise (Stergiou and Browman, 2005), suggesting a lack of interdisciplinary experience at the level of review. Within *L&O*, however, publication rates of marine and freshwater papers have been nearly equal since about 1970. We cannot ignore the potential for foci journals to select for self-similarity (i.e., one will read and cite papers from where one publishes). Given the similar cross-citation disparity between specialty journals and the overall rate within *L&O*, however, we suspect that this effect is minimal or works in concert with other factors. We therefore ask whether system differences—real or perceived —or cultural differences play a role in the cross-citation disparity between limnologists and oceanographers.

Was Redfield wrong in suggesting the common ecological principles shared by marine and lacustrine systems outweighed the differences? In part due to perimeter to volume ratios and influence by terrestrial systems, it has been suggested that lacustrine and marine systems differ in ways that could profoundly affect the physics, biogeochemistry and the life-histories of organisms, and that the two systems are not as comparable as previously thought. Classic paradigms would suggest that marine systems physics vary on longer time scales compared to lake systems (Steele, 1985). Similarly, classic paradigms hold that nitrogen (N) limitation is relatively more important in marine systems, compared to phosphorus (P) (Hecky and Kilham, 1988) or N-P co-limitation (Elser et al., 2007) for lakes. This view ignores the high frequency dynamics associated with coastal regions (e.g., Huyer et al., 1983) as well as the role of P-limitation in open ocean regions where primary and export production is supported by nitrogen fixation (e.g., Dore et al., 2002; Karl et al., 2012) or the role of N:P ratios influencing primary production in eutrophic lakes (Smith and Schindler, 2009).

An alternative scenario is that differences between limnology and oceanography, are in part due to lakes having higher experimental tractability than oceans (Paine, 2005), thus the divide may actually reflect not the system one studies, but whether one can, or chooses to, manipulate it. Indeed, within *L&O* where citation frequency was sufficient to investigate potential factors, there were no differences in cross-citation frequency between limnological and oceanographic papers amongst experimental studies (odds ratio=1.01, $p=0.5$), although the representation of experimental studies was relatively low for both disciplines (15 and 16%, respectively). This suggests that when investigators seek and are able to address questions through manipulation, there is ample cross-pollination. Conversely, the high cross-citation disparity between the two disciplines amongst observational papers (LIM/OCE: odds ratio=3.3, $p<0.05$) may be a function of study foci, theoretical considerations, scale, and tools used to analyze patterns.

While we cannot address institutional or geographical biases in this current effort, examining temporal trends may illuminate historical biases that have shaped the paradigmatic lenses through which we practice and teach the next generation of scientists. In particular, the cross-citation disparity within *L&O* during the 1980s bears further scrutiny. During this period and the preceding decade, there was a focus on whole lake manipulation experiments to evaluate the effects of water chemistry and food web architecture on phytoplankton dynamics, fishes, and ecosystem processes (i.e., trophic cascades, cultural eutrophication, acid rain; e.g., Carpenter and Kitchell, 1988; Schindler et al., 1985). In the marine realm, the dynamics of temperature and phytoplankton, especially in coastal zones, were being studied through remotely sensed radiometry (e.g., Abbot and Zion, 1985). Concurrently, and perhaps relatedly, biological oceanographers were conducting geographical comparisons of biophysical phenomena (e.g., upwelling: Brink et al., 1983). Thus, the cross-citation disparity evident during that period, and perhaps reflected in the specialty journals, may echo an age-old division: limnology courts terrestrial and intertidal ecology, considering top-down and bottom-up controls of ecosystem functioning, whereas biological oceanography courts physics, focusing on bottom-up regulation (Banse, 2012).

We used meta-analyses in an attempt to provide an objective perspective to trends and biases in the cross-pollination of ideas between limnologists and oceanographers. We found that limnologists tend to cross-identify and presumably cross-train more frequently than oceanographers. While biologists tended to cross train more equally between the two disciplines than chemists or physicists, cross-citation frequency amongst ecological papers in habitat-specific journals also revealed a disparity. Across the specialty journals surveyed, limnologists were far more likely to cite ecological studies published in marine-specific journals than oceanographers were likely to cite the reciprocal.

We suggest that each discipline may benefit by acknowledging and borrowing the paradigmatic lens of the other. The cross-citation disparity within *L&O* has decreased in recent history, suggesting that the delineation between the disciplines of limnology and oceanography is becoming more porous, with increasing cross-fertilization of methodologies, ideas, or both. We are entering a new age in the aquatic sciences, fostered by interdisciplinary programs such as Eco-DAS, in which scientists from both limnology and oceanography recognize the global and urgent nature of environmental issues and the utility of sharing their ideas and methods.

We recognize that freshwater and marine systems are both incredibly diverse and that paradigmatic divisions, driven by both ecological and sociological differences, also exist within disciplines. However, rather than focusing solely on the challenges related to diversity of habitats (and diversity of scientists

working within them), future studies should delve into what exactly is being shared (e.g., methodologies: metagenomics, mesocosms) and what presently is not (speci?c statistical tools, ecosystem models, and concepts). For example, at a very basic, yet fundamental level, freshwater ecologists have bene?ted by the natural delineation of ecosystem boundaries afforded by the watershed and lakeshore (Cole, 2005) that constrains experi- mental design and analysis of observed patterns. As ecological oceanographers recognize the existence of and are able to consistently identify natural boundaries (e.g., Longhurst, 2007; Devred et al., 2007) the apparent differences between freshwater and marine systems may become minimal as ecological concepts and methods are transferred and tested.

REFERENCES

Abbott, M. R. and P.M. Zion. 1985. Satellite observations of phytoplankton variability during an upwelling event. Cont. Shelf Res. 4:661–680.

Banse, K. 2012. Re?ections about Chance in my career, and on the top–down regulated world. Ann. Rev Mar. Sci. 5: 1–19, doi:10.1146/annurev–marine–121211–172359, 2013.

Brink, K. H., Halpern, D., Huyer, A. and R.L. Smith. 1983. The physical environment of the Peruvian upwelling system. Prog. Oceanogr, 12: 285–305.

Carpenter, S. R. and J.F. Kitchell. 1988. Consumer control of lake productivity. Bioscience 38: 764–769.

Cole, J. J. 2005. Communication between terrestrial and marine ecologists : loud, sometimes abrasive, but healthy and occasionally useful: Bridging the gap between aquatic and terrestrial ecology. Mar. Ecol. Prog. Ser. 304: 272–274.

Devred, E., Sathyendranath, S. and T. Platt, T. 2007. Delineation of ecological provinces using ocean colour radiometry. Mar. Ecol. Prog. Ser. 346: 1–13.

Dore, J. E., Brum, J. R., Tupas, L. M. and D.M. Karl. 2002. Seasonal and interannual variability in sources of nitrogen supporting export in the oligotrophic subtropical North Paci?c Ocean. Limnol. Oceanogr. 47: 1595–1607.

Elser, J. J., Bracken, M. E., Cleland, E. E., Gruner, D. S., Harpole, W. S., Hillebrand, H. and J.E. Smith. 2007. Global analysis of nitrogen and phosphorus limitation of primary producers in freshwater, marine and terrestrial ecosystems. Ecol Lett. 10:1135–1142.

Hecky, R. E. and P. Kilham. 1988. Nutrient limitation of phyto- plankton in freshwater and marine environments: a review of recent evidence on the effects of enrichment. Limnol. Oceanogr. 33:796–822.

Huyer, A. (1983). Coastal upwelling in the California Current system. Progress in Oceanography, 12(3), 259–284

Longhurst, A. R. 2007. Ecological Geography of the Sea. Academic Press. UK.

Menge, B. A. et al. 2009. Terrestrial ecologists ignore aquatic literature: Asymmetry in citation breadth in ecological publications and implications for generality and progress in ecology. J. Exp. Mar. Biol. Ecol. 377: 93–100.

Paine RT 2005. Cross environment talk in ecology: fact or fantasy? In: Stergiou KI, Browman HI (eds) Bridging the gap between aquatic and terrestrial ecology. Mar. Ecol. Prog. Ser. 304:280–283.

Red?eld, A. C. 1956. Announcement. Limnol. Oceanogr. 1: 1.

Schindler, D. W. et al. (1985) Long–term ecosystem stress: the effects of years of experimental acidi?cation on a small lake. Science 228: 1395.

Smith, V. H. and D.W. Schindler. 2009. Eutrophication science: where do we go from here?. Trends Ecol. Evol. 24: 201–207.

Steele, J. H. 1985. A comparison of terrestrial and marine ecological systems. Nature, 313: 355–358.

Stergiou KI, and H.I. Browman. 2005. Imbalances in the report- ing and teaching of ecology from limnetic, oceanic, and terrestrial domains. Mar. Ecol. Prog. Ser. 304:280–283.