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GUSTAVO ALDA MARTINS

Trends and challenges in alternative states in freshwater ecosystems:
emphasizing the role of invasive species in state shifts

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Dissertação apresentada ao programa de Pós-Graduação em Ecologia de Ambientes Aquáticos Continentais do Departamento de Biologia, Centro de Ciências Biológicas da Universidade Estadual de Maringá, como requisito parcial para obtenção de título de Mestre em Ecologia e Limnologia.
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Orientador: Prof. Dr. Roger Paulo Mormul
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Dedico esse trabalho a todos aqueles que contribuíram para sua realização e ao meu eu futuro: nunca se esqueça de olhar para trás quando não souber para onde ir.

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Tendências e desafios sobre estados alternativos em ambientes de águadoce: enfatizando o papel das espécies invasoras nos *state shifts*

RESUMO

Lagos rasos são os ecossistemas de água doce mais abundantes do planeta, suportam elevada diversidade de espécies e proveem diversos serviços ecossistêmicos, porém, a dinâmica natural desses ecossistemas está ameaçada devido ao estabelecimento de espécies invasoras não nativas. Apesar do crescente interesse acerca dos impactos que espécies invasoras não nativas causam nos ecossistemas invadidos, pouco ainda se sabe sobre a influência delas para a estabilidade e mudança de estado trófico em lagos rasos. Foi realizada uma revisão sistematizada da literatura para identificar quais termos, espécies, definições e objetivos foram mais abordados nesses estudos, assim como identificar possíveis padrões e tendências globais quanto à distribuição das pesquisas ao longo dos anos e seu local de origem. Embora tenha havido um crescimento na quantidade de estudos publicados nas últimas três décadas sobre estados tróficos em ambientes aquáticos, apenas uma pequena quantidade deles aborda a influência das espécies invasoras nãonativas na mudança de estado trófico nestes ecossistemas. Foram exploradas as possíveis razões e as consequências que esses padrões e métodos trazem para essa área da ecologia, de forma que a discussão aqui feita sugere diversas recomendações para futuros trabalhose pesquisadores considerarem.

Palavras-chave: Eutrofização. Invasão biológica. Revisão sistemática.

Trends and challenges in alternative states in freshwater ecosystems: emphasizing the role of invasive species in state shifts

ABSTRACT

Despite growing interest in the effects of non-native invasive species in changing alternative trophic states in shallow lakes, little is known when it comes to tropical regions. We carried out a systematic review to identify which terms, species, definitions and objectives were most addressed in these studies, as well as to identify possible global patterns and trends regarding the growth of these research over the years and the hot spots of publications. Our results showed that although there was a non-linear growth in the number of studies published in the last three decades regarding state shifts in freshwater environments, only a small number of them addresses the influence that non-native invasive species have in triggering trophic states changes in aquatic environments and even less in shallow lakes. In our discussion, we explore the possible reasons and consequences that these patterns bring to this area of ecology, as well as expand the results and make the work available so that it can be used as recomendation for future projects related to the topic.

Keywords: Freshwater. Eutrophication. Biological invasions. Systematic review.

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SUMMARY

1 INTRODUCTION

The study of freshwater ecosystems and shallow lakeshas increased in the last 50 years as an attempt to understand problems related to anthropogenic pressures on freshwaters (Jeppesen et al., 2012; Phillips et al., 2016). As shallow lakes can shift between macrophyte-dominated clear water and plankton-dominated turbid water depending on the nutrient loadings (Jeppesen et al., 1998), understanding the nutrient dynamics and their impacts on aquatic communities have been one of the worldwide researcher's efforts (Jeppesen et al., 2007). Despite the advances controlling nutrient loadings and manipulating aquatic communities to maintain clear water conditions, many challenges remain for researchers regarding the specific conditions that each environment is subjected to (Jeppesen et al., 2012). For instance, the classical shift between clear and turbid water may present several triggers that lead to mechanisms of change such as water level variation (Geest et al., 2007), fish migration (Mormul et al., 2012), top-down (Jeppesen et al., 1998) and bottom-up (Bergman et al., 1999) controls, and lake flushing (Hilt et al., 2011).

In addition,studiesfocusing on shallow lakes are biased geographically, because they are more frequently carried out in the temperate region (Scheffer & Carpenter, 2003). However, records of lake shifts are rising in the tropics, particularly in the last two decades (e.g., Moi et al., 2021 Mormul et al., 2012; Schooler et al., 2011; Loverde-Oliveira et al., 2009). Moreover, recent findings suggest that tropical and subtropical lakes have triggers and shifting mechanisms similar to temperate regions. For example, top-down and bottom-up controls seem to be generalized mechanisms that lead lakes to shift between submerged macrophyte-dominated clear water and plankton-dominated turbid water in temperate (Jeppesen et al., 1998; Scheffer et al., 1993), tropical and subtropical regions (Moi et al., 2021; Mormul et al., 2012). On the other hand, floating macrophyte-dominated turbid water records are most common in the tropics (e.g., Moi et al., 2022; Schooler et al., 2011).

Invasive species may play a key role as the change generator trigger in the invaded ecosystem (Emery-Butcher, Beatty & Robson, 2020), which includes transitions between ecosystem states (Gaertner et al., 2014).Some invasive species can also be considered invasive ecosystem engineers (Emery-Butcher, Beatty & Robson, 2020). An example of an invasive engineering species is *Pontederia crassipes* (commonly known as water hyacinth), a floating macrophyte native to Brazil, but invasive in multiple ecosystems worldwide(Ashton, 1989). This species can grow and spread quickly on the water surface, making dense “green carpets” that drastically reduce underwater radiation, directly affecting submerged macrophytes and facilitating a state shift (Ashton, 1989). Also, the isopod *Sphaeromaquoyanum*, native to east Australia, has been introduced to the North American marshes, where it creates a gallery of small subterranean tunnels resulting in less sediment stability, shifting the current marsh ecosystem into a mud pool (Talley et al., 2001). Despite the increasing records of engineering species causing state shifts in freshwaters, most records demonstrating invasive species triggering regime shifts seem to be recorded in terrestrial ecosystems (Gaertner et al., 2014), while little is reported for freshwaters.

Invasive species can also play a secondary role in the state shiftbased on the driver-passenger models applied to invasions. One the one hand, if interactive processes are responsible for native species decline, then the removal of the invasive species should increase the richness and abundance of the native species - the “driver” model.On the other hand if the invasive species are not the limiting factor, then their eradication should have a minimal impact - the “passenger” model (Didham et al., 2005). Therefore, the role that the invasive species had or still have in the ecosystem translates directly into its establishment and disturbance capacity (Blackburn & Ewen, 2017) and the process that should be carried out to restore the ecosystem. Identifying if the invasive species is a driver or passenger in the state shift remains a challenge that links both ecological concepts (e.g., Didham et al., 2005).

Here, we conducted a systematic review of published studies that reported the regime shifts in freshwater systems (from 1945 to 2020), recognizing the invasive species as the lead or supporting factor in the state shifts. Specifically, we aimed to (i) identify trends, knowledge gaps, and publication biases among studies investigating the regime shifts in freshwater systems driven by invasive species; (ii) analyze which species are most related to regime shift; (iii) discuss how studies on this topic have been carried out so far, providing recommendations for future research, pointing out potential shortfalls.

2 METHODS

We searched for primary research articles published in English that developed research involving state shifts in shallow lakes with the presence of invasive species. We used the *Web of Science* core collection and the *Scopus* databases, including articles published between 1945 and 2020. The search was conducted in August 2021 through a keyword-driven approach. As our baseline of searchwe used the following terms: ("*regime shift**" OR "*state shift**" OR "*alternative state**" OR "*stable state**" OR "*alternative stable state**" OR "*state shift driver**") AND ("*freshwater**" OR "*shallow lake**" OR "*lagoon**" OR "*floodplain lakes**") AND ("*alienspecies*" OR "*invasivespecies*" OR "*exoticspecies*" OR "*non-nativespecies*" OR "*nonnativespecies*" OR "*invasivealienspecies*" OR "*non-indigenous species*") for both databases. The systematic search was performed using the 'ecology', 'limnology' and 'environmental science' topic fields on *Web of Science* and 'Agricultural and Biological Sciences'(AGRI) subject area on *Scopus*.

The search resulted in 1,126 primary articles. We evaluated the titles to exclude studies out of the scope (n = 279) of our systematic review (i.e., we selected studies focused on inland water ecosystems and ecology subjects). Then, we excluded duplicates between the search platforms (n = 84). We evaluated the abstracts of the remaining articles (n = 763) to confirm whether the study met the established previous criteria (studies on shallow freshwater lakes, recording the state shifts and involving invasive species), removing those that did not fit (n = 687). Finally, we read the full text of the remaining 76 articles, from which 21 were excluded as they did not completely fit our inclusion criteria. All the processes in this review followed the PRISMA guidelines ("*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*") with detailed criteria for the inclusion or exclusion of studies in the systematic review (Moher et al., 2009; Fig. 1).

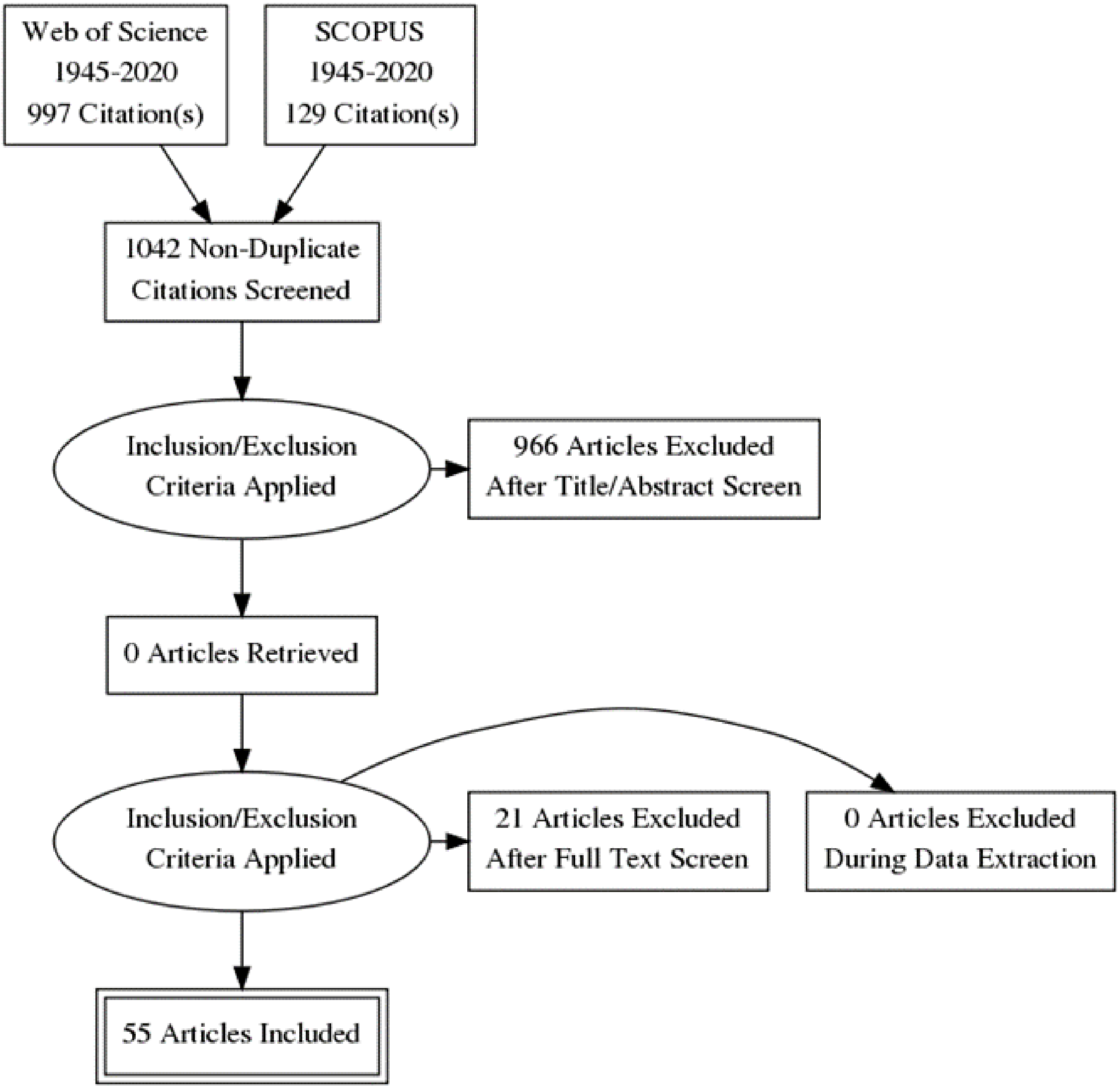

Figure 1. Summary of studies' inclusion and exclusion stages. Preferred Reporting Items for Systematic Reviews and Meta-Analyzes (PRISMA; Moher et al. 2009) flow diagram made on < http://prisma.thetacollaborative.ca/>. The details regarding the reasons for excluding articles during the screening of abstracts and full texts are also provided**.**

In the 55 retained articles (Appendix), we recorded: 1) the geographical location of the studies; 2) main taxonomic groups studied; 3) types of environments (e.g., lake, shallow-lake, river) 4) the role of the invader according to the authors or determined using the data presented by them (i.e., “passenger” or “driver”); 5) dominant ecosystem state in the environment; 6) variable used to determine the ecosystem state.

We also considered articles presenting mesocosm experiments. In these cases, we consider the authors extrapolation to the natural environment from which the species were collected to the experiment and add the article information to our categories. In addition, the data presented here do not necessarily represent the number of articles *per se*, as not all the retained articles presented all the information of interest. Also, some articles presented information from more than one ecosystem or species; these articles were counted more than once when necessary.

3 RESULTS

3.1 **Temporal trends and geographical emphasis**

We found a general increased interest in the topic of state shifts in shallow lakes in the past few decades. Although we have searched articles since 1945, the record growth seems to start later in 1989 (Fig. 2). After the initial publication by Balls, Moss, & Irvine (1989) about the transition between dominant states in shallow lakes, there has been a boom in interest in the subject, going from 1 to 4 papers per year to dozens per year after the 2000s. This growth tendency has increased over the years, reaching 60 published papers in 2015 and almost 90 published papers in 2020. In contrast, according to our search, the records of articles mentioning state shift and species invasion in the same study started only in 2008 with the publication of Lougheed et al. (year), Reineke et al. (year) and Strayer et al. (year). Although a slight growth trend appeared after this period, it did not follow the general trend of growth related to state shift articles in general (Fig. 2). At last, we have noticed that the vast majority of papers was published in regions of temperate climate, which accounted for 76% (n = 42) of the total number of publications, while the remaining 24% was distributed between subtropical climates regions (n = 7), tropical (n = 4) and equatorial (n = 2).

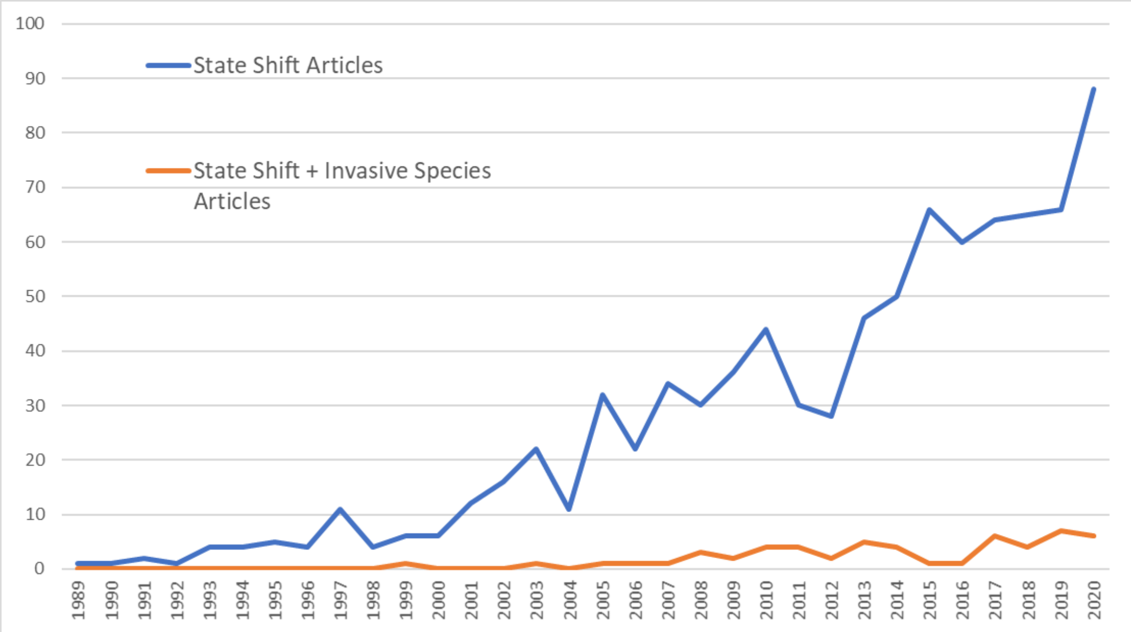

Figure 2: Distribution of published articles over the years. The blue line represents the articles with “State Shift” as the main focus, not necessarily containing invasive species. The orange line represents articles with “State Shift” and “Invasive Species” as the main focus.

3.2 **On the invasive species and state shifts**

Invasive species appeared clearly in 52 out of the 55 articles, identified at the species level, while in the remaining three articles, they appeared with upper classifications. In total, the authors registered 70 invasive species, with the zebramussel*Dreissena polymorpha* (n = 7), the common carp *Cyprinus carpio*(n = 5), the red-swamp-crayfish *Procambarusclarkii*(n = 4)and the macrophyte *Egeria densa*(n = 4)being the most commonly found invasive species among the articles. Moreover, authors suggested or clearly mentioned the role of invasive species as a lead or supporting actor in the state shift in 35 articles (63%), from which 23 articles (65%) reported that the presence of the invasive species could have triggered or fastened the state shift in the ecosystem as a driver.

Over half of the articles (n = 32; 58%) did not classify the trophic state of the studied ecosystem; only eight articles classified the state as clear waters (oligotrophic) and 18 as turbid waters (eutrophic). Also, there was a lack of details about the variables used to determine the trophic state in 31 articles. Among the studies that specified this information, the main variables used as a proxy for the trophic state were the concentration of the nutrient (n = 4), reduction or lack of submerged macrophytes (n = 5), the dominance of submerged macrophytes (n = 7) or turbidity (n = 6).

Among the most studied taxa, there was a clear predominance of studies in which fishes are the main subject (n = 53) (Fig. 3), in all ecosystem types (Fig. 4). Aquatic macroinvertebrates received almost half the attention when compared to fishes (n = 30), followed by macrophytes (n = 18) (Fig. 3), while few studies considered zoo/phytoplankton (n = 4), terrestrial plants (n = 6) and reptiles (n = 1). Concerning the ecosystems researched, there is a dominance of articles that took place in medium to big lakes (i.e., depth superior to 5 m or when specified by the author) (n = 23), followed by rivers (n = 16), shallow lakes (n = 10), reservoirs (n = 5), wetlands (n = 5) and ponds (n = 4) (Fig. 4).

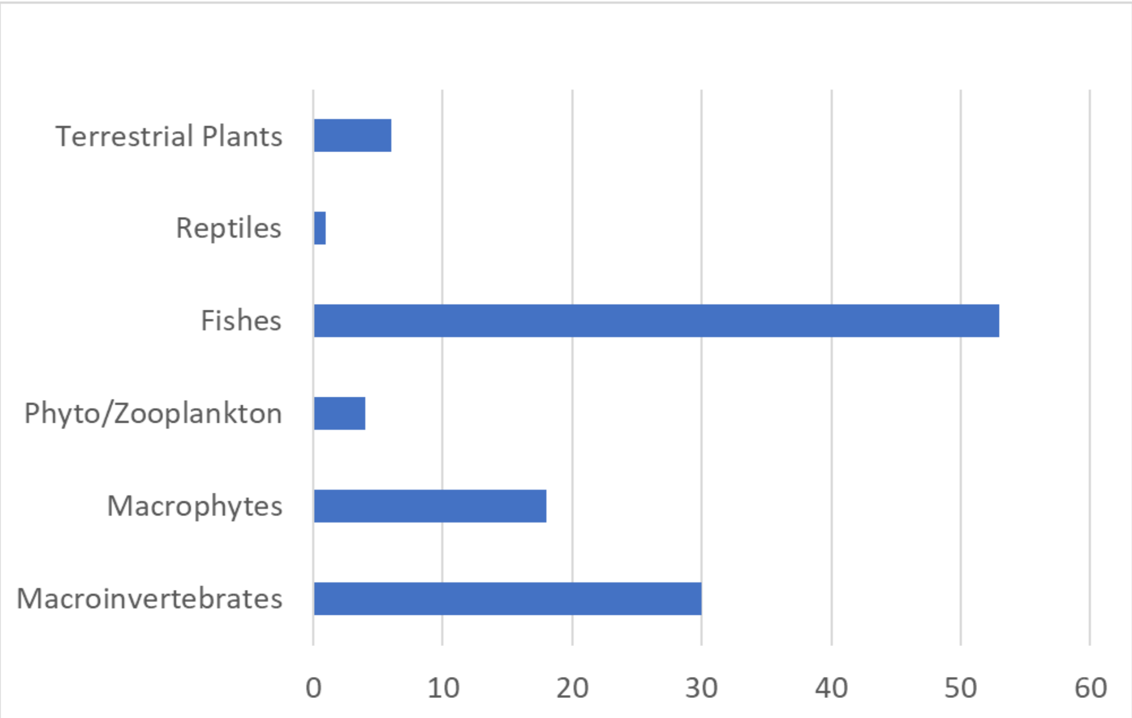

Figure 3: Number of included papers included by taxa in our systematic review about the relation of exotic species and state shifts.

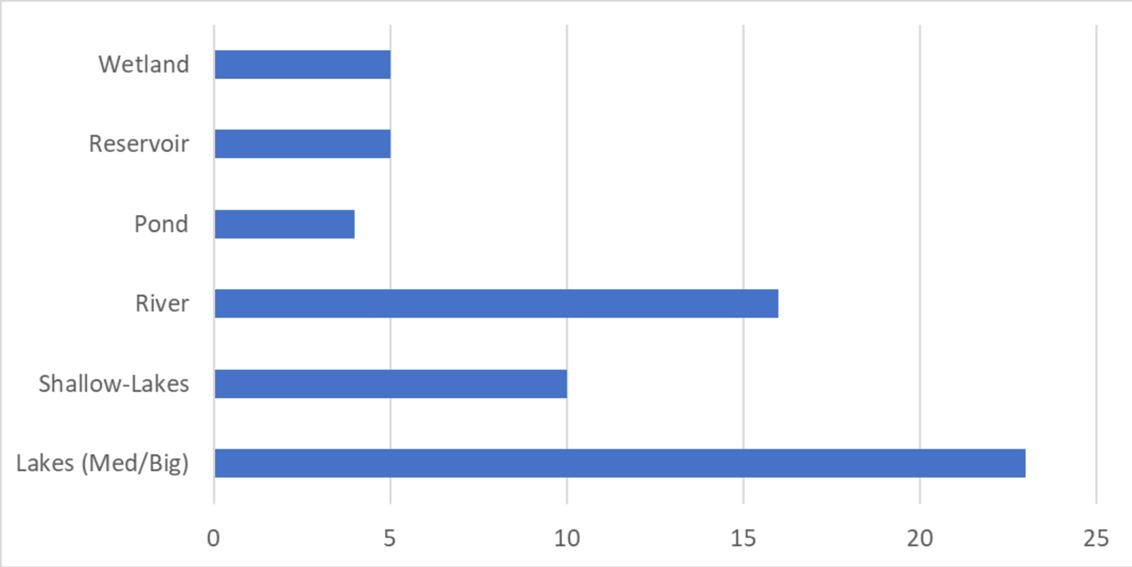

Figure 4: Number of included papers by type of ecosystemour systematic review about the relation of exotic species and state shifts.

4 DISCUSSION

4.1 State shifts and the lack of standardization

We have synthesized the historical data regarding the consequences of invasive species on regime shifts in freshwater ecosystems through the review of published papers. The notion that aquatic ecosystems can abruptly change to another alternate stable state opposite to each other is not new information (Scheffer et al., 1993). The variation between turbid water state dominated by algae to clear water with a high abundance of submerged macrophytes has been demonstrated in many systems in the latest two decades (e.g., Hilt et al., 2017; Mormul et al., 2012; Scheffer & Jeppesen, 2007). Despite this empirical demonstration of regime shift throughout the time, our results showed that around 58% of the published papers on alternative stable states in freshwater did not present detailed data about how the current stable state was characterized (or the temporal variation in regime shifts) of the studied ecosystem. This lack of data about the characterization of the current state of the ecosystem consists of a major flaw and makes it impossible for readers to correctly evaluate whether this environmental change is, for example, seasonal and expected or areal regime state shift. Also, among the studies that characterized the current dominant state, we noticed a lack in standardization, as to determine the ecosystem state many parameters such as nutrient concentration, cyanobacteria total biomass, macrophyte biomass and sedimentation rates were used (Leigh et al., 2010). This lack of standardization to determine the ecosystem state is highly detrimental for readers to acknowledge similar macroecological patterns that could be emerging in multiple regions, independent of the ecosystem type. However, not all seems to be in disarray, as multiple articles were successful in providing enough data about the parameters used to determine the trophic state of the ecosystem, being nutrient concentration, cyanobacteria total biomass, macrophyte biomass and sedimentation rates being the main metrics used by the authors, which is on par with previous similar observations (Leigh et al., 2010).

As a final note on this topic, the lack of both data may suggest that a few impediments are happening during the projection and execution of these researches: an impossibility of determining which is the dominant trophic state due to fast and constants changes during the timeframe which the research took place (Yang et al., 2008), the dominant trophic state may not be the main focus of the work, commonly happening in experiments that took place in laboratories or it was simply information neglected by the authors.

4.2 Invasive species as possible drivers of regime shifts

The number of reports of species invasions have seen an increase worldwide, reaching peak numbers in the last decade (Pyšek& Richardson, 2010). While some invasive species cause mild disturbances and changes in the local communities, others have the potential to deeply change the landscape and the functioning of the invaded ecosystem (Hansen et al., 2013; Hui et al., 2013). By accounting this crescent frequency of biological invasions worldwide, the importance of maintaining an updated registry with the more problematic species – local and globally – has become not just relevant for ecological research, but for also a fundamental economic issue.

When we analyzed the most commonly studied invasive species, it became clear that the primary focus of these studies is such species that can cause economic losses (Richardson &Pyšek, 2008; Sousa et al., 2013; Underwood et al., 2006; Yick et al., 2021). By being expensive processes, the restoration and management of invaded freshwater ecosystems need not only a series of detailed studies around it, but a plateau of robust data to better understand the role that the invasive species took on the invaded ecosystem (Seabloom & van der Valk, 2003), this role being the one of driver or passenger. However, it is safe to assume that these classifications are not statis, which suggests that the same species can assume both the roles of driver and passenger at different times of their establishment and dispersion period.

Considering the *invasional meltdown* hypothesis proposed by Simberloff& Von Holle (1999), we cannot disregard the possibility that multiple invasive species registered in the same ecosystem simultaneously could be affecting in a more negative and intense way the native species, even accelerating the triggering of a state shift (Christian, 2001; Hay et al., 2004). Some interactions can be clearer than others, requiring only a handful of observations and analysis, while others might need long term studies before reaching robust conclusions (Kuebbing& Nuñez, 2016).

4.3 Ecological and geographical distribution of papers

We observed that most of the papers on the regime shifts in shallow lakes driven by invasive species were made and published in temperate climate regions, above the northern hemisphere. This geographical-bias in the studies may be the factor underlying why lakes are the most studied ecosystem type, fish are the most studied taxonomic group, and zebramusselis the most common invasive species related to regime shift. This is because most lakes, including shallow ones, are located in temperate climate regions (Downing et al, 2006), while reservoirs, hydroelectric power plants and wetlands are majoritarian found in tropical and subtropical regions (Zarfl et al., 2015). Also, in general, fish have the most economical impact among the other groups in temperate regions (Pimentel, Zuniga, & Morrison, 2005) than in tropical regions, where the flora and fauna are much more diverse and the food web much more complex (Brown, 2014; Raven et al. 2020). Lastly, zebramussel is an invasive species with a wide distribution range specially in the northern hemisphere, where they have been disrupting the locals ecosystems, with losses being estimated at $1 billion each year in the US and £5 million spent each year in boat washing, hull sealing and mechanical control of zebra mussel in the UK (Oreska and Aldridge, 2011).

5 FINAL CONSIDERATIONS

Although it may seem that the main scope of this work was focused on the lacking side of the theme, the studies of freshwater ecosystems and state shifts have grown by leaps and bounds in the last decades (Kosten et al., 2012; Phillips, Willby, & Moss, 2016). This review showed the main obstacles faced by researchers planning on or already working with state shifts and the ecology of invasions. Perhaps, future research might require the application of multiple hypothesis approaches, which allows strong inference about the underlying processes that link both ecological concepts (*sensu*Platt 1964). We summarized the most common patterns and trends that researchers worldwide tend to cling to, as well as the results obtained, and data analyzed in each paper. Still, we believe that these results can be further strengthened by a quantitative analysis such as a meta-analysis focused review.In addition, the contribution from other researchers can - and surely will - serve as building point to the development and growth of field as a whole, leading to more meaningful insights .We suggest that a standardization of terms, definitions and data collected would facilitate the development of the study area, as well as improve the overall quality of the studies, leading to increasingly more shareable and accessible data worldwide. We understand that standardization is difficult, thus, we suggest focusing on the basic data first, like the characterization of the ecosystem and the metrics utilized to measure it. Lastly, we think that greater efforts in understanding the particularities of invasive species and their relations to state shifts should be directed towards tropical and subtropical ecosystems, seeing that the tip of the iceberg has barely been touched.

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Yick, J. L., Wisniewski, C., Diggle, J., & Patil, J. G. (2021). Eradication of the invasive common carp, Cyprinus carpio from a large lake: Lessons and insights from the tasmanian experience. *Fishes*, *6*(1). https://doi.org/10.3390/fishes6010006

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APPENDIX A - List of included articles.

Authors	Title	Published On	Year
Van Nes, EH; van den Berg, MS; Clayton, JS; Coops, H; Scheffer, M; van Ierland, E	A simple model for evaluating the costs and benefits of aquatic macrophytes	HYDROBIOLOGIA	1999
Leck, MA	Seed-bank and vegetation development in a created tidal freshwater wetland on the Delaware River, Trenton, New Jersey, USA	WETLANDS	2003
Rodriguez, CF; Becares, E; Fernandez-Alaez, M; Fernandez-Alaez, C	Loss of diversity and degradation of wetlands as a result of introducing exotic crayfish	BIOLOGICAL INVASIONS	2005
Willis, Theodore V.; Magnuson, John J.	Response of fish communities in five north temperate lakes to exotic species and climate	LIMNOLOGY AND OCEANOGRAPHY	2006
Ribeiro, F; Orjuela, RL; Magalhaes, MF; Collares-Pereira, MJ	Variability in feeding ecology of a South American cichlid: a reason for successful invasion in mediterranean-type rivers?	ECOLOGY OF FRESHWATER FISH	2007
Reinecke, M. K.; Pigot, A. L.; King, J. M.	Spontaneous succession of riparian fynbos: Is unassisted recovery a viable restoration strategy?	SOUTH AFRICAN JOURNAL OF BOTANY	2008
Lougheed, VL; McIntosh, MD;	Wetland degradation leads to	FRESHWATER	2008

Parker, CA; Stevenson, RJ	homogenization of the biota at local and landscape scales	BIOLOGY	
Strayer, DL; Pace, ML; Caraco, NF; Cole, JJ; Findlay, SEG	Hydrology and grazing jointly control a large-river food web	ECOLOGY	2008
Marin, Victor H.; Tironi, Antonio; Delgado, Luisa E.; Contreras, Manuel; Novoa, Fernando; Torres-Gomez, Marcela; Garreaud, Rene; Vila, Irma; Serey, Italo	On the sudden disappearance of Egeria densa from a Ramsar wetland site of Southern Chile: A climatic event trigger model	ECOLOGICAL MODELLING	2009
Matsuzaki, Shin-ichiro S.; Usio, Nisikawa; Takamura, Noriko; Washitani, Izumi	Contrasting impacts of invasive engineers on freshwater ecosystems: an experiment and meta-analysis	OECOLOGIA	2009
Mouthon, Jacques; Daufresne, Martin	Long-term changes in mollusc communities of the Ognon river (France) over a 30-year period	FUNDAMENTAL AND APPLIED LIMNOLOGY	2010
Gido, Keith B.; Dodds, Walter K.; Eberle, Mark E.	Retrospective analysis of fish community change during a half-century of landuse and streamflow changes	JOURNAL OF THE NORTH AMERICAN BENTHOLOGICAL SOCIETY	2010
Fang, Ling; Wong, Pak Ki; Lin, Li; Lan, Chongyu; Qiu, Jian-Wen	Impact of invasive apple snails in Hong Kong on wetland macrophytes, nutrients, phytoplankton and filamentous algae	FRESHWATER BIOLOGY	2010

Bond, N; McMaster, D; Reich, P; Thomson, JR; Lake, PS	Modelling the impacts of flow regulation on fish distributions in naturally intermittent lowland streams: an approach for predicting restoration responses	FRESHWATER BIOLOGY	2010
Marchi, Michela; Jorgensen, Sven Erik; Becares, Eloy; Corsi, Ilaria; Marchettini, Nadia; Bastianoni, Simone	Dynamic model of Lake Chozas (Leon, NW Spain)-Decrease in eco-exergy from clear to turbid phase due to introduction of exotic crayfish	ECOLOGICAL MODELLING	2011
Nicholls, K. H.; Hoyle, J. A.; Johannsson, O. E.; Dermott, R.	A biological regime shift in the Bay of Quinte ecosystem (Lake Ontario) associated with the establishment of invasive dreissenid mussels	JOURNAL OF GREAT LAKES RESEARCH	2011
Mihaljevic, M; Stevic, F	Cyanobacterial blooms in a temperate river-floodplain ecosystem: the importance of hydrological extremes	AQUATIC ECOLOGY	2011
Matsuzaki, SS; Takamura, N; Arayama, K; Tominaga, A; Iwasaki, J; Washitani, I	Potential impacts of non-native channel catfish on commercially important species in a Japanese lake, as inferred from long-term monitoring data	AQUATIC CONSERVATION-MARINE AND FRESHWATER ECOSYSTEMS	2011
Daga, VS; Gubiani, EA	Variations in the endemic fish assemblage of a global freshwater	ACTA OECOLOGICA-INTERNATIONAL JOURNAL OF	2012

	ecoregion: Associations with introduced species in cascading reservoirs	ECOLOGY	
Angeler, DG; Allen, CR; Johnson, RK	Insight on Invasions and Resilience Derived from Spatiotemporal Discontinuities of Biomass at Local and Regional Scales	ECOLOGY AND SOCIETY	2012
Hansen, Gretchen J. A.; Ives, Anthony R.; Vander Zanden, M. Jake; Carpenter, Stephen R.	Are rapid transitions between invasive and native species caused by alternative stable states, and does it matter?	ECOLOGY	2013
Sandlund, Odd Terje; Gjelland, Karl Oystein; Bohn, Thomas; Knudsen, Rune; Amundsen, Per-Arne	Contrasting Population and Life History Responses of a Young Morph-Pair of European Whitefish to the Invasion of a SpecialisedCoregonid Competitor, Vendace	PLOS ONE	2013
Fischer, Jesse R.; Krogman, Rebecca M.; Quist, Michael C.	Influences of native and non-native benthivorous fishes on aquatic ecosystem degradation	HYDROBIOLOGIA	2013
Brandner, Joerg; Auerswald, Karl; Cerwenka, Alexander F.; Schliewen, Ulrich K.; Geist, Juergen	Comparative feeding ecology of invasive Ponto-Caspian gobies	HYDROBIOLOGIA	2013
Stevic, F; Cerba, D; Cakalic, IT; Pfeiffer, TZ; Vidakovic, J; Mihaljevic, M	Interrelations between Dreissena polymorpha colonization and autotrophic periphyton	FUNDAMENTAL AND APPLIED LIMNOLOGY	2013

	development - a field study in a temperate floodplain lake		
Marroni, Soledad; Iglesias, Carlos; Mazzeo, Nestor; Clemente, Juan; Teixeira de Mello, Franco; Pacheco, Juan P.	Alternative food sources of native and non-native bivalves in a subtropical eutrophic lake	HYDROBIOLOGIA	2014
van de Wolfshaar, Karen E.; HilleRisLambers, Reinier; Goudswaard, Kees P. C.; Rijnsdorp, Adriaan D.; Scheffer, Marten	Nile perch (Lates niloticus, L.) and cichlids (Haplochromis spp.) in Lake Victoria: could prey mortality promote invasion of its predator?	THEORETICAL ECOLOGY	2014
Tucker, Andrew J.; Williamson, Craig E.	The invasion window for warmwater fish in clearwater lakes: the role of ultraviolet radiation and temperature	DIVERSITY AND DISTRIBUTIONS	2014
Collas, Frank P. L.; Koopman, K. Remon; Hendriks, A. Jan; van der Velde, Gerard; Verbrugge, Laura N. H.; Leuven, Rob S. E. W.	Effects of desiccation on native and non-native molluscs in rivers	FRESHWATER BIOLOGY	2014
Daga, VS; Skora, F; Padial, AA; Abilhoa, V; Gubiani, EA; Vitule, JRS	Homogenization dynamics of the fish assemblages in Neotropical reservoirs: comparing the roles of introduced species and their vectors	HYDROBIOLOGIA	2015
Viana, Duarte S.; Cid, Bertha; Figuerola, Jordi;	Disentangling the roles of diversity resistance and priority effects in	OECOLOGIA	2016

Santamaria, Luis	community assembly		
Nishijima, Shota; Nishikawa, Chisato; Miyashita, Tadashi	Habitat modification by invasive crayfish can facilitate its growth through enhanced food accessibility	BMC ECOLOGY	2017
Tuckett, Quenton M.; Simon, Kevin S.; Kinnison, Michael T.	Cultural Eutrophication Mediates Context-Dependent Eco-Evolutionary Feedbacks of a Fish Invader	COPEIA	2017
Fera, Shannon A.; Rennie, Michael D.; Dunlop, Erin S.	Broad shifts in the resource use of a commercially harvested fish following the invasion of dreissenid mussels	ECOLOGY	2017
Van Colen, W; Portilla, K; Ona, T; Wyseure, G; Goethals, P; Velarde, E; Muylaert, K	Limnology of the neotropical high elevation shallow lake Yahuarcocha (Ecuador) and challenges for managing eutrophication using biomanipulation	LIMNOLOGICA	2017
Weeks, AM; De Jager, NR; Haro, RJ; Sandland, GJ	SPATIAL AND TEMPORAL RELATIONSHIPS BETWEEN THE INVASIVE SNAIL BITHYNIA TENTACULATA AND SUBMERSED AQUATIC VEGETATION IN POOL 8 OF THE UPPER MISSISSIPPI RIVER	RIVER RESEARCH AND APPLICATIONS	2017

Ding, CZ; Jiang, XM; Xie, ZC; Brosse, S	Seventy-five years of biodiversity decline of fish assemblages in Chinese isolated plateau lakes: widespread introductions and extirpations of narrow endemics lead to regional loss of dissimilarity	DIVERSITY AND DISTRIBUTIONS	2017
Rejmankova, Eliska; Sullivan, Benjamin W.; Aldana, Jose R. Ortiz; Snyder, Jenise M.; Castle, Stephanie T.; Morales, Fatima Reyes	Regime shift in the littoral ecosystem of volcanic Lake Atitlan in Central America: combined role of stochastic event and invasive plant species	FRESHWATER BIOLOGY	2018
Strange, E. F.; Hill, J. M.; Coetzee, J. A.	Evidence for a new regime shift between floating and submerged invasive plant dominance in South Africa	HYDROBIOLOGIA	2018
Gacia, Esperanca; Buchaca, Teresa; Bernal-Mendoza, Nayeli; Sabas, Ibor; Ballesteros, Enric; Ventura, Marc	Non-native Minnows Threaten Quillwort Populations in High Mountain Shallow Lakes	FRONTIERS IN PLANT SCIENCE	2018
Noda, H; Ohkawara, K	Long-term Changes in Age Structures of a Naturalized Population of Freshwater Turtle, Red-eared Slider Trachemys scripta elegans	CURRENT HERPETOLOGY	2018
Sirbu, I; Benedek, AM	Trends in Unionidae (Mollusca, Bivalvia) communities in Romania: an analysis of environmental gradients and	HYDROBIOLOGIA	2018

	temporal changes		
Mofu, Lubabalo; Cuthbert, Ross N.; Dalu, Tatenda; Woodford, Darragh J.; Wasserman, Ryan J.; Dick, Jaimie T. A.; Weyl, Olaf L. F.	Impacts of non-native fishes under a seasonal temperature gradient are forecasted using functional responses and abundances	NEOBIOTA	2019
Strange, Emily F.; Landi, Pietro; Hill, Jaclyn M.; Coetzee, Julie A.	Modeling Top-Down and Bottom-Up Drivers of a Regime Shift in Invasive Aquatic Plant Stable States	FRONTIERS IN PLANT SCIENCE	2019
Crossetti, Luciane Oliveira; Bicudo, Denise de Campos; Bini, Luis Mauricio; Dala-Corte, Renato Bolson; Ferragut, Carla; de Mattos Bicudo, Carlos Eduardo	Phytoplankton species interactions and invasion by Ceratiumfurcoides are influenced by extreme drought and water-hyacinth removal in a shallow tropical reservoir	HYDROBIOLOGIA	2019
He, Liang; Bakker, Elisabeth S.; Nunez, Marta M. Alirangues; Hilt, Sabine	Combined effects of shading and clipping on the invasive alien macrophyte Elodea nuttallii	AQUATIC BOTANY	2019
Wegner, B; Kronsbein, AL; Gillefalk, M; van de Weyer, K; Kohler, J; Funke, E; Monaghan, MT; Hilt, S	Mutual Facilitation Among Invading Nuttall's Waterweed and Quagga Mussels	FRONTIERS IN PLANT SCIENCE	2019
Jiang, XM; Ding, CZ; Brosse, S; Pan, BZ; Lu, Y; Xie, ZC	Local rise of phylogenetic diversity due to invasions and extirpations leads to a regional phylogenetic homogenization of fish fauna from Chinese isolated	ECOLOGICAL INDICATORS	2019

	plateau lakes		
Strayer, DL; Adamovich, BV; Adrian, R; Aldridge, DC; Balogh, C; Burlakova, LE; FriedPetersen, HB; G-Toth, L; Hetherington, AL; Jones, TS; Karatayev, AY; Madill, JB; Makarevich, OA; Marsden, JE; Martel, AL; Minchin, D; Nalepa, TF; Noordhuis, R; Robinson, TJ; Rudstam, LG; Schwalb, AN; Smith, DR; Steinman, AD; Jeschke, JM	Long-term population dynamics of dreissenid mussels (Dreissena polymorpha and D. rostriformis): a cross-system analysis	ECOSPHERE	2019
Liu, Ying; He, Liang; Hilt, Sabine; Wang, Rui; Zhang, Huan; Ge, Gang	Shallow lakes at risk: Nutrient enrichment enhances top-down control of macrophytes by invasive herbivorous snails	FRESHWATER BIOLOGY	2020
Goto, Daisuke; Dunlop, Erin S.; Young, Joelle D.; Jackson, Donald A.	Shifting trophic control of fishery-ecosystem dynamics following biological invasions	ECOLOGICAL APPLICATIONS	2020
Bouska, Kristen L.; Houser, Jeffrey N.; De Jager, Nathan R.; Drake, Deanne C.; Collins, Scott F.; Gibson-Reinemer, Daniel K.; Thomsen, Meredith A.	Conceptualizing alternate regimes in a large floodplain-river ecosystem: Water clarity, invasive fish, and floodplain vegetation	JOURNAL OF ENVIRONMENTAL MANAGEMENT	2020
Sarvala, Jouko; Helminen, Harri;	Invasive submerged macrophytes complicate	HYDROBIOLOGIA	2020

Heikkila, Jukka	management of a shallow boreal lake: a 42-year history of monitoring and restoration attempts in Littoistenjarvi, SW Finland		
Kaeding, Lynn R.	New climate regime started and further shaped the historic Yellowstone Lake cutthroat trout population decline commonly attributed entirely to nonnative lake trout predation	AQUATIC ECOLOGY	2020
Mormul, Roger Paulo; Thomaz, SidineiMagela; Jeppesen, Erik	Do interactions between eutrophication and CO_2 enrichment increase the potential of elodeid invasion in tropical lakes?	BIOLOGICAL INVASIONS	2020