Supporting Information

Contents

1.0 Explanation of Methods

To begin to explore the use and interdisciplinary nature of the *hydrologic connectivity* concept, we conducted a cursory literature review using R statistical software (R Core Team, 2018), the bibliometrix package (Aria and Cuccurullo, 2017), and methods similar to Bernhardt et al., (2017). To do this, we queried the ISI Web of Knowledge database for articles that used the term "hydrologic connectivity" between 1998 and 2018. We then discretized those articles by journal discipline; classified keywords by physical, chemical, or biological function; and finally, identified keywords that referred to specific hydrologic units. Below, we provide examples tables that demonstrate how journals and key terms were classified. Further, we provide the Rcode used to create Figure 1.

2.0 Example Journal Classification

We classified journals into 5 categories: hydrology, ecology, biogeochemistry, environmental science, and general earth science. All journals were assigned to a single category. Note, categories are similar to those used in Bernhardt et al., (2017). See Table 1 for examples of how journals were categorized.

Table 1: Separation of journals into distinct disciplinary categories

Journal	Count	Disciplinary Category
Hydrological Processes	42	hydrology
Water Resources Research	39	hydrology
Wetlands	17	environmental science
River Research And Applications	14	hydrology
Geomorphology	13	earth science
Journal Of Geophysical Research-Biogeosciences	13	biogeochemistry
Journal Of Hydrology	13	hydrology
Journal Of The American Water Resources Association	12	hydrology
Hydrology And Earth System Sciences	10	hydrology
Ecohydrology	8	hydrology

3.0 Example Functional Classification

We identified key words that related to physical, chemical, and biological functions of aquatic systems from across the selected manuscripts. Individual keywords could only relate to one functional category, but each paper could contain key words from multiple functional categories. See Table 2 for examples of how key words were categorized.

Table 2: Classification of key words by function

Key work	Count	Function
HYDROLOGIC CONNECTIVITY	181	Physical
CONNECTIVITY	110	Physical
NITROGEN	40	Chemical
GROUNDWATER	39	Physical
HYDROLOGIC	38	Physical
FLOW	37	Physical
RUNOFF	33	Physical
ECOSYSTEMS	30	Biological
LAND-USE	29	Physical
PATTERNS	29	Physical

4.0 Example Hydrologic Unit Designation

We also identified key words that related to diffent hydrologic units. Individual keywords could only relate to one hydrologic unit, but each paper could be tied to multiple hydrologic units. See Table 3 for examples of how key words were categorized.

Table 3: Classification of key words by hydrologic unit

Key work	Count	Hydrologic unit
CATCHMENT	37	Watersheds and Stream Networks
RIVER	34	Rivers and Streams
LANDSCAPE	26	Watersheds and Stream Networks
RIPARIAN ZONES	24	Riparian Zones and Floodplains
HEADWATER STREAMS	22	Rivers and Streams
STREAMS	22	Rivers and Streams
GEOGRAPHICALLY ISOLATED WETLANDS	18	Wetlands
BASIN	17	Watersheds and Stream Networks
SOIL	17	Critical Zone, Hillslopes, and Soils
STREAM	17	Rivers and Streams

5.0 Rcode

```
####################################################################################
#Step 1:  Setup Workspace-----------------------------------------------------------
####################################################################################
#Clear Memory
rm(list=ls(all=TRUE))

#required packages
library(tidyverse)    #tidyverse family of packages
library(gridExtra)    #plotting
library(treemapify)   #plotting
library(packcircles)  #plotting
library(bibliometrix) #bibliography analysis
library(lubridate)    #date analysis
library(readxl)       #data import
```

```r
#Define working directory
working_dir<- #Insert working directory here

###############################################################################
#Step 2:  Wrangle Citaiton Data------------------------------------------------
###############################################################################
#Import .bib file info
#read .bib file
bib<-readFiles(paste0(working_dir,"connectivity_lit.bib"))

#Convert to df
bib<-convert2df(bib, dbsource = 'isi', format='bibtex')

#create summary
results <- biblioAnalysis(bib, sep = ";")
results <- summary(object = results, k=500, pause = F)

#read in manual classification tables (see tables 1-3 for examples)
journals<-read_excel(paste0(working_dir,"classification.xlsx"), sheet="journals")
key_words<-read_excel(paste0(working_dir,"classification.xlsx"), sheet="key_words")
hydro_units<-read_excel(paste0(working_dir,"classification.xlsx"), sheet="hydro_units")

###############################################################################
#Step 3:  Plotting-------------------------------------------------------------
###############################################################################
#A) Publication rate over time------------------------------------------------
#create tibble of year and # of pubs
df<-as_tibble(results$AnnualProduction)
colnames(df)<-c("year", "pubs")
df$year<-as.numeric(paste(df$year))

#create exponential model
model<-lm(log(pubs)~year, df)
model_data<-tibble(x=df$year, y=exp(fitted(model)))

#create plot
p1<-df %>%
  #Start plotting device
  ggplot(aes(x=year, y=pubs)) +
  #Add points
  geom_point(col="grey30") +
  #Add exp model
  geom_line(data = model_data,
            aes(x, y),
            col="grey70",
            size=1.3,
            linetype = 2) +
  #Add text describing model
  geom_text(aes(x=2003, y=75), label="RSQ=0.94\np<0.001", col="grey30")+
  #Axis labels
  labs(x="Year", y = "Number of Publications") +
  #Add Theme Elements
  theme_bw(base_size=12) +
```

```
  theme(
    #bold font for both axis text
    axis.text=element_text(face="bold"),
    #set thickness of axis ticks
    axis.ticks=element_line(size=0.4),
    #remove plot background
    plot.background=element_blank(),
    #Decrease right margin for final plot
    plot.margin=unit(c(5.5, 12, 5.5, 5.5), "points")
  )

#B) Treemap of discpline and journal---------------------------------------------
#create tibble of journal and number of pubs
df<-as_tibble(results$MostRelSources) %>%
  #Rename collumns
  rename(journal = `Sources       `, pubs=Articles) %>%
  #format collumns
  mutate(#trim white space in journal names
         journal = paste(trimws(journal)),
         #make pubs numeric
         pubs = as.numeric(paste(pubs))
         ) %>%
  #Remove journals with <4 citations
  filter(pubs>3) %>%
  #left join with journal classification table
  left_join(.,journals) %>%
  #redo journal names
  mutate(journal=str_to_title(journal))

#Create color pallete matrix
color<- tibble(classification = c("environmental science","hydrology",
                                  "ecology","biogeochemistry", "earth science"),
             org=c(4,2,3,1,5))
df<-left_join(df, color) %>%
  arrange(org) %>%
  mutate(color = factor(org))

#Plot tree map
p2<-ggplot(df, aes(area = pubs, label=journal, subgroup = classification, fill=color)) +
  geom_treemap() +
  geom_treemap_text(colour = "white", place = "centre",grow = F, reflow=T) +
  geom_treemap_subgroup_border(lwd=0.2, col="grey90") +
  scale_fill_brewer(palette="Set1") +
  theme_bw() +
  theme(legend.position="none")

#C) Circle plot of functions-----------------------------------------------------
#Add unique ID to bib tibble
bib$UID<-seq(1, nrow(bib))

#Create long-fromat tibble with ID and key word (for both author and ISI defined IDs)
w1<-tibble(ID = bib$UID, key_word = bib$ID) %>%
  #create long format
```

```r
  separate_rows(., key_word,sep=";") %>%
  #trim white space
  mutate(key_word = trimws(paste(key_word)))
w2<-tibble(ID = bib$UID, key_word = bib$DE) %>%
  #create long format
  separate_rows(., key_word,sep=";") %>%
  #trim white space
  mutate(key_word = trimws(paste(key_word)))
w<-bind_rows(w1, w2)

#Estimate number of pubs
df<-key_words %>%
  #format key words tibble
  select(key_word, class) %>%
  filter(str_detect(class, "function")) %>%
  #join tibbles [ie journal key words and key word classifications]
  left_join(w, .) %>%
  #select unique combinations of ID and class
  na.omit(.) %>%
  select(ID, class) %>%
  distinct(ID, class) %>%
  #tally functions represented by different pubs
  count(class)

#setup plotting layout
packing<-circleProgressiveLayout(df$n, sizetype = "area")
df <- cbind(df, packing)
df.gg<-circleLayoutVertices(packing, npoints = 50)
df.gg$value=rep(df$class, each=51)

#Format Names for text
df$class[df$class=="biological function"]<-"Biological"
df$class[df$class=="chemical function"]<-"Chemical"
df$class[df$class=="physical function"]<-"Physical"

#plot
p3<-ggplot() +
  #Plot Polygongs
  geom_polygon(data = df.gg,
               aes(x, y, group = id, fill=as.factor(id)),
               colour = "black") +
  scale_fill_manual(values = c("#4daf4a","#e41a1c",  "#377eb8")) +
  #Add text
  geom_text(data = df, aes(x, y, label = paste0(class,"\n[n=",n,"]"), size=4)) +
  #theme
  theme_void(base_size = 12) +
  theme(legend.position="none") +
  coord_equal()

#D) Lolly-pop plot of hydrologic units------------------------------------------
#Create tibble of publication counts
df<-tibble(ID = bib$UID, key_word = bib$ID) %>%
  #create long format
```

```
  separate_rows(., key_word,sep=";") %>%
  #trim white space
  mutate(key_word = trimws(paste(key_word))) %>%
  #join hydro units classification table
  left_join(. , hydro_units) %>%
  #Remove irrelivant key words
  select(ID, hydro_units) %>%
  na.omit(.) %>%
  distinct(.) %>%
  #Tally hydro units
  count(hydro_units)

#preserve order in plot by changing hydro_units to factor
df<- df %>%
  arrange(n) %>%
  mutate(hydro_units = factor(hydro_units, hydro_units))

#Create plot
p4<-ggplot(df, aes(x=hydro_units, y=n)) +
  #Add lollipops
  geom_segment(aes(x=hydro_units, xend=hydro_units, y=0, yend=n), color="grey30") +
  geom_point(col="blue", size=4, alpha=0.8) +
  #Add lables
  labs(x="Hydrologic Units", y="Number of Publications")+
  #Add theme info
  theme_bw(base_size = 12) +
  coord_flip() +
  theme(
    panel.grid.major.y = element_blank(),
    panel.border = element_blank(),
    axis.ticks.y = element_blank(),
    axis.text.y =  element_text(margin=margin(l=2), hjust=1)
  )

#Export multi plot -------------------------------------------------------
plot_grid(p1,p2,p3,p4,
          nrow = 2, rel_widths = c(1.18,2), rel_heights = c(1.25, 1),
          labels = c("A)","B)","C)", "D)"), label_size = 11,
          label_x=c(0,-0.05, 0, -0.05))
ggsave(paste0(working_dir, "figure1.pdf"), device="pdf",
       width = 7.07, heigh=4.99, units="in")
```

6.0 Works Cited

Aria, M., C. Cuccurullo. 2017. "bibliometrix: An R-tool for comprehensive science mapping analysis." *Journal of Informatics* 11(4): 959-975. doi: 10.1016/j.joi.2017.08.007.

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