Synthesizing Ecohydrology Models as a Management Tool for Landscape Conservation

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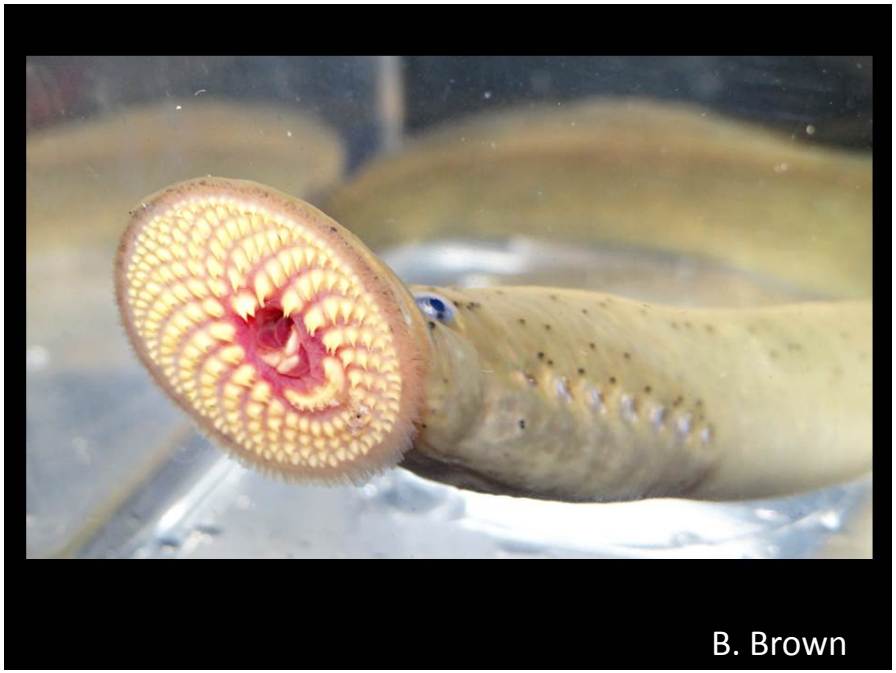
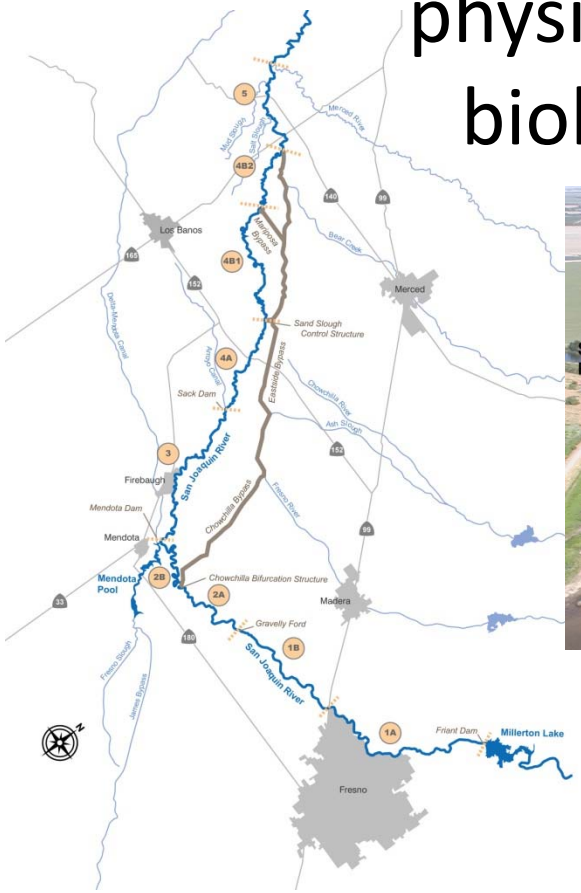
Introduction

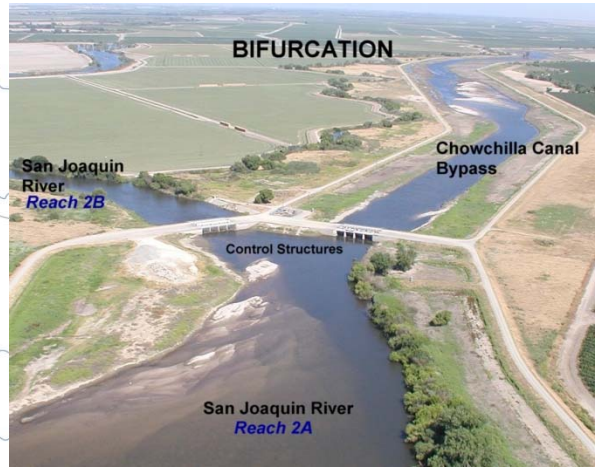
- Historically, clearly defined disciplinary boundaries
- Development from single-disciplinary studies to multi- and inter-disciplinary studies
  - e.g., ecohydraulics: parallel developments between physical and biological sciences

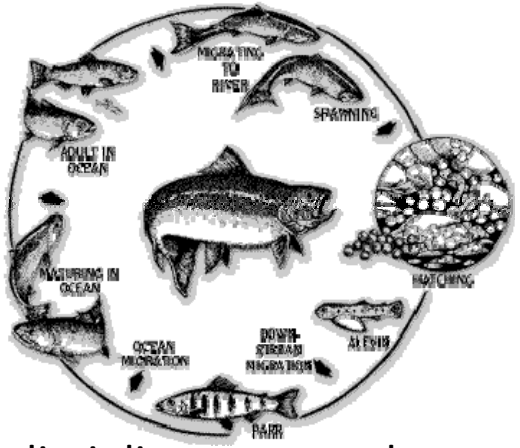


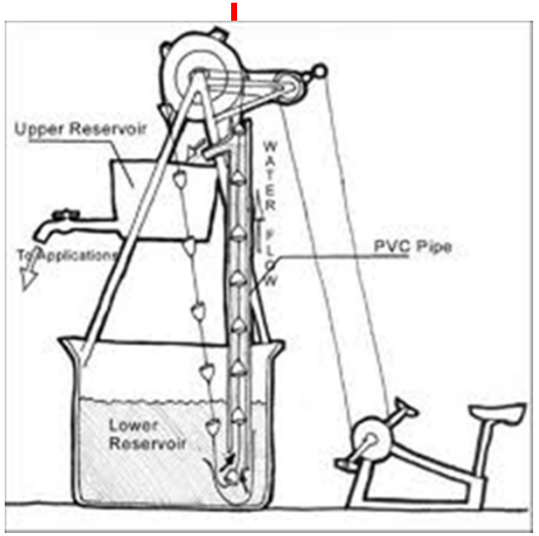
How does turbulence influence the migration of lamprey?

Structured by the physical, chemical, and biological processes









Interdisciplinary research teams needed to address complex issues

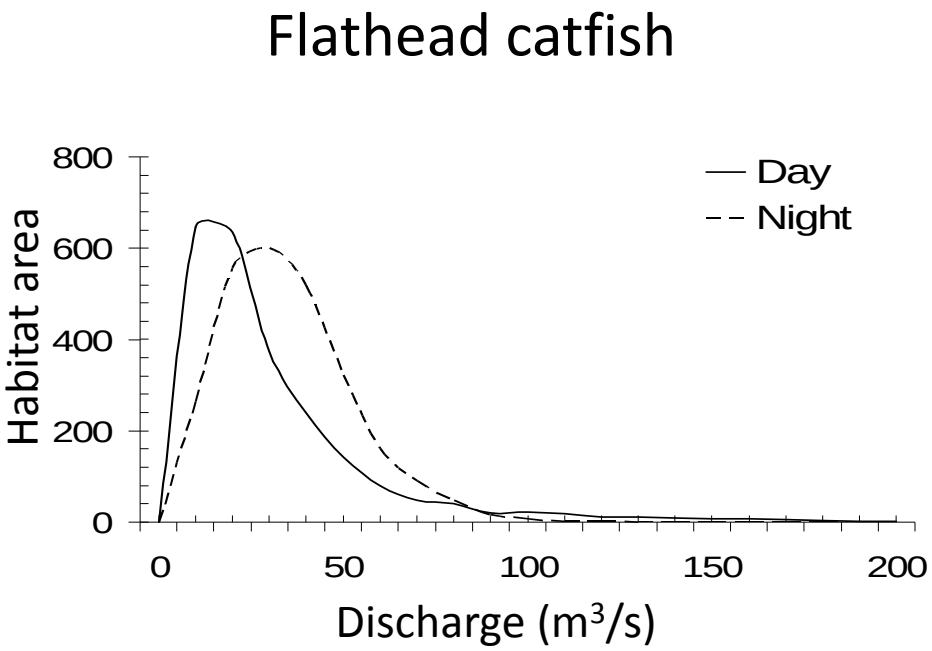
Interdisciplinary research: emerging fields

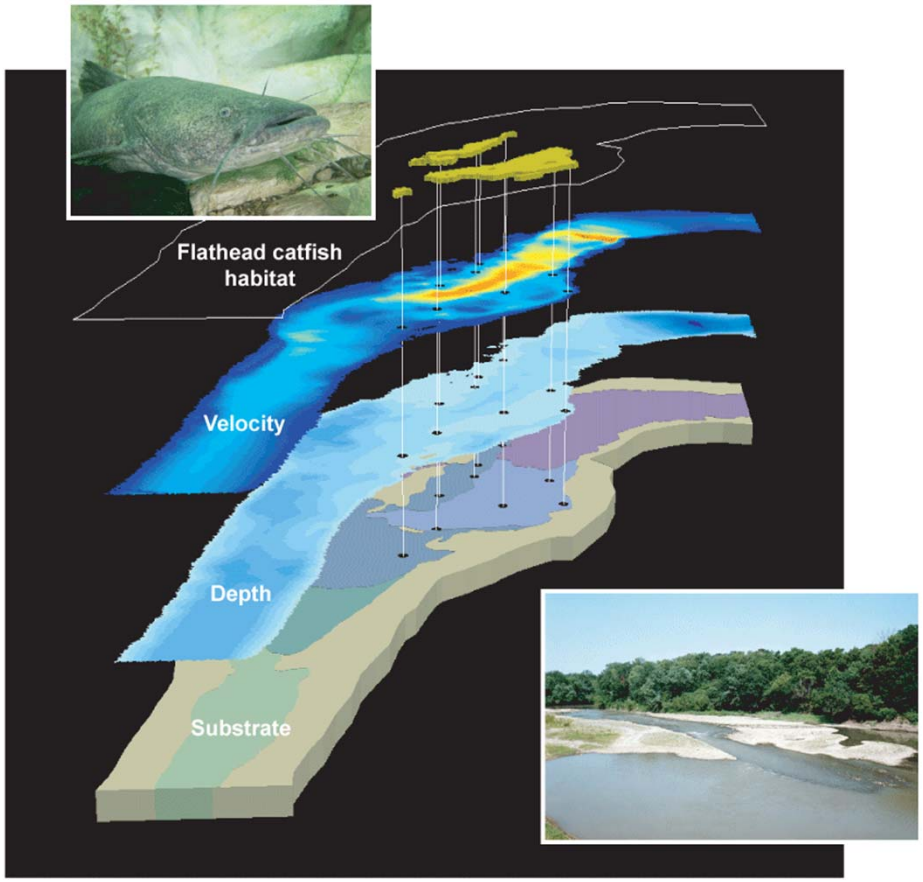
- Ecohydrology- interface of hydrology and ecology
- Ecohydraulics- water motion and ecology

- Ecologists
- Geomorphologists
- Engineers
- Hydrologists
- Water-resource managers

Sustain both natural ecosystems and the demands placed on them by society

Environmental flows as an example





Model development

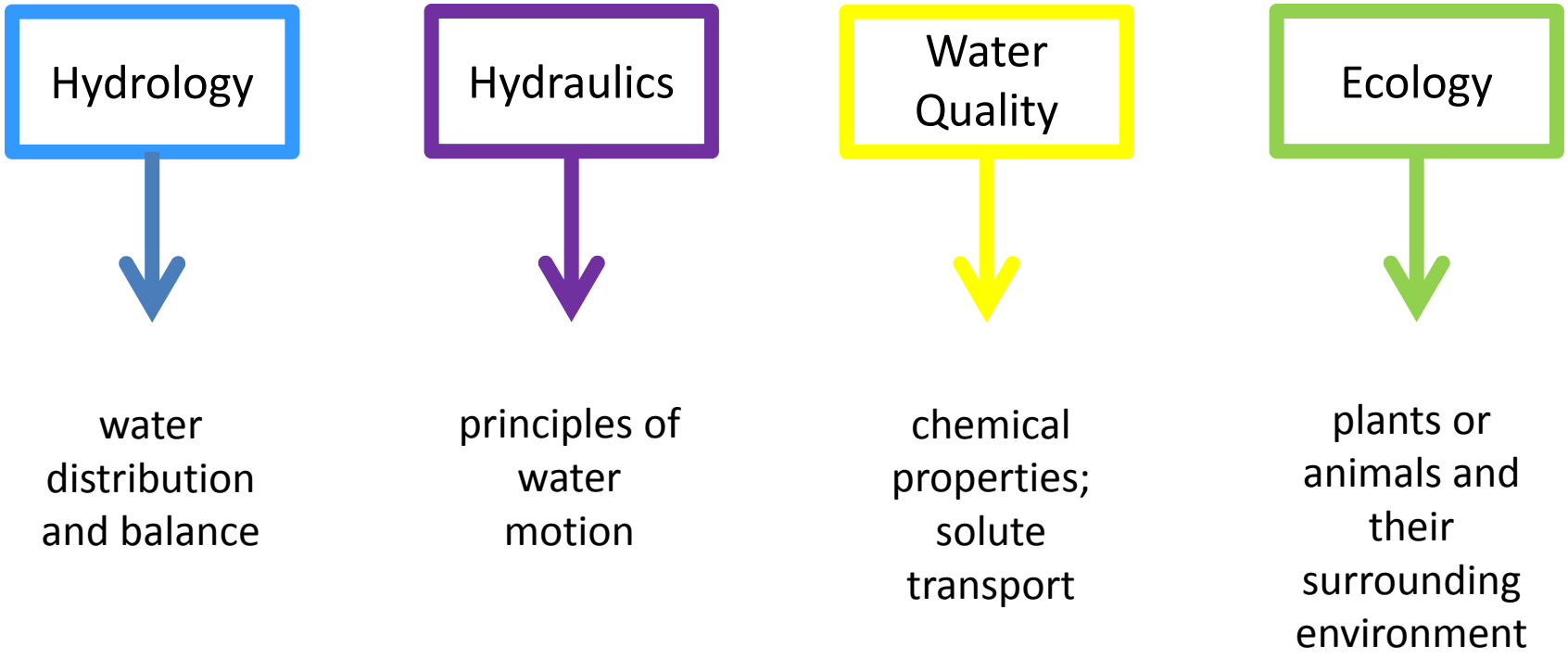
- Models associated with hydrology, hydraulics, and ecology are often developed independently
- Number of models has increased considerably
- Which models are most useful for which applications?
- How can models be combined to answer complex questions?
- Initiatives with broader spatial boundaries (e.g., LCC)

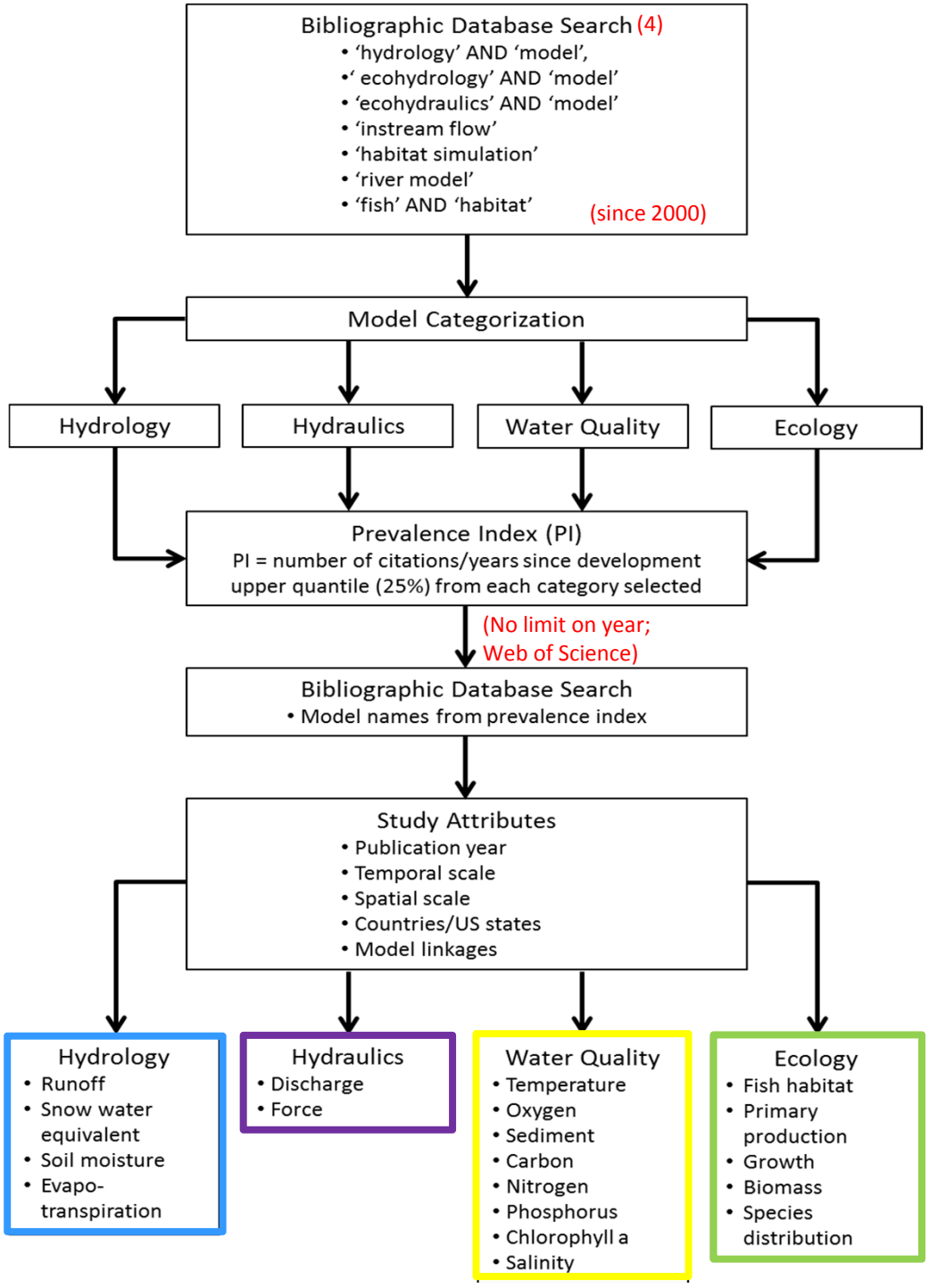
Objective

- Systematically evaluate prevailing hydrologic/hydraulic and ecological models to increase our understanding of the simulation potential

Methods

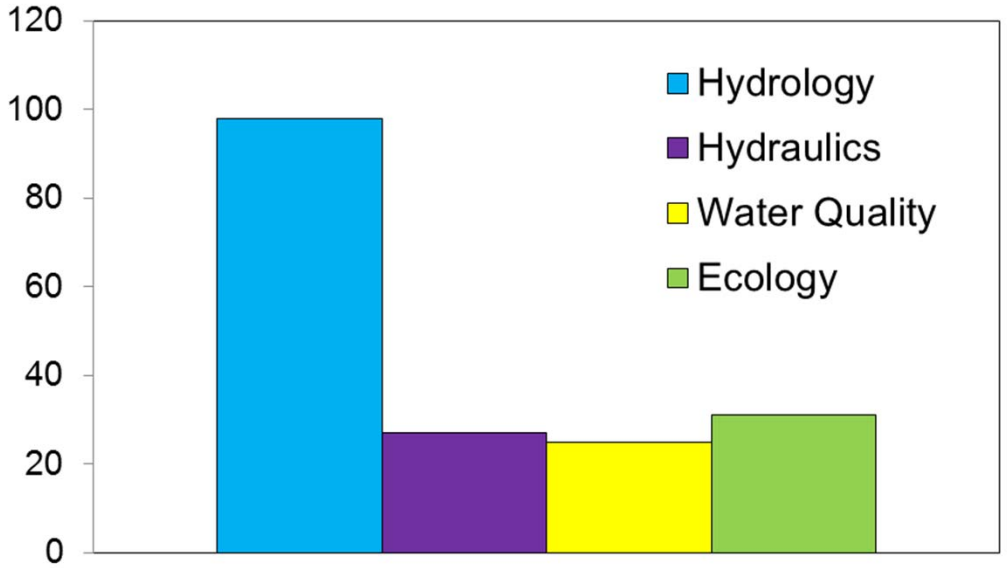
- Vote counting meta-analysis to highlight how models are used and bias in application




Bibliographic Database Search (4)
• 'hydrology' AND 'model',
•' ecohydrology' AND 'model'
• 'ecohydraulics' AND 'model'
• 'instream flow'
• 'habitat simulation'
• 'river model'
• 'fish' AND 'habitat'
(since 2000)
Model Categorization
Hydrology
Hydraulics
Water Quality
Ecology
Prevalence Index (PI)
PI = number of citations/years since development
upper quantile (25%) from each category selected
(No limit on year;
Web of Science)
Bibliographic Database Search
• Model names from prevalence index
Study Attributes
• Publication year
• Temporal scale
• Spatial scale
• Countries/US states
• Model linkages
Hydrology
• Runoff
• Snow water equivalent
• Soil moisture
• Evapo-transpiration
Hydraulics
• Discharge
• Force
Water Quality
• Temperature
• Oxygen
• Sediment
• Carbon
• Nitrogen
• Phosphorus
• Chlorophyll a
• Salinity
Ecology
• Fish habitat
• Primary production
• Growth
• Biomass
• Species distribution

Results

- 178 ecohydrology and ecohydraulics models identified
- Several models could belong to more than one category (e.g., PHABSIM)
- Models usage generally fell into one of four categories



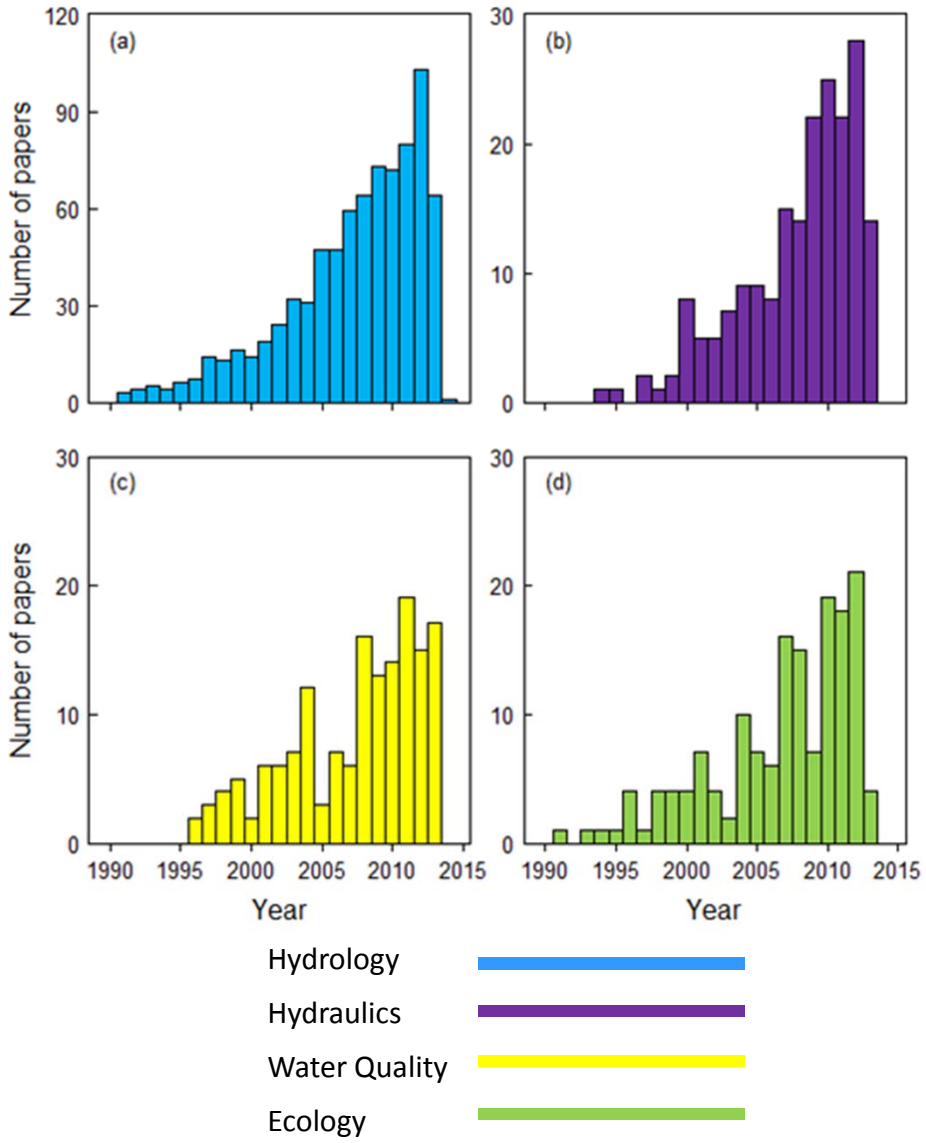
1. Extended use and wide application
2. Long history but being replaced by newer approaches
3. New models with rapid appeal
4. New models yet to catch on

Results

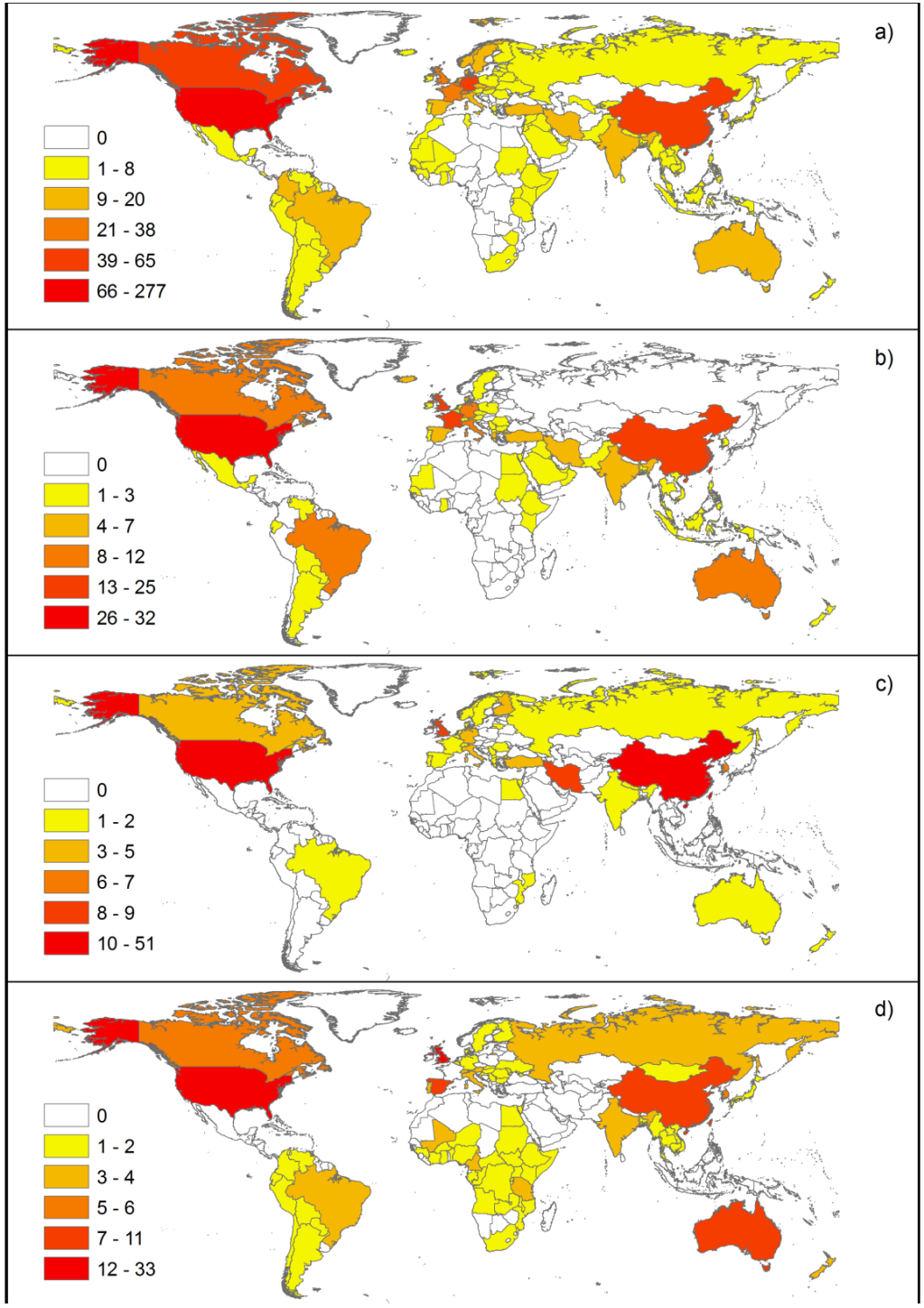
Model	PI	Model	PI	Model	PI	Model	PI	Model	PI
Hydrology Models									
AGNPS	0.90	FLATWOODS	0.24	KINEROS2	0.44	REWASH	0.25	THROW	1.00
ANSWERS	0.14	FLUVIAL-12	0.41	KW-GIUH	0.17	RHEM	0.67	TOPKAPI	0.91
BASINS*	1.88	ForHyM	0.38	LARSIM	0.17	RHESSys*	1.35	TR-55	0.90
BBH-B	0.29	ForNBM	0.60	LASCAM	0.08	SAC-SMA	1.95	TREX	0.33
BROOK90	1.15	GENESYS	0.75	LISEM	1.88	SCS-CN	7.71	tRIBS + VEGGIE	1.11
CASC2D	1.11	GLDAS	0.23	LISFLOOD	3.69	SEBAL	0.63	VIC	11.9
CAT	1.00	GRHUM	0.08	L-THIA	1.08	SHAW	0.50	Vmod	0.29
CEQUEAU	0.40	HBV	4.00	MATSIRO	0.58	SHETRAN	1.95	WASH123D	0.75
CHARM	0.13	HEC-6	0.96	MESH	1.00	SIMGRO	0.48	WaSiM-ETH	4.08
CRASH	0.13	HEC-HMS	3.65	MGB-IPH	1.83	SIMHYD	1.64	WASHCLASS	0.45
CREAMS	0.76	HL-RDHM	1.33	MIKE-SHE	6.45	SLURP	1.00	WATFLOOD	1.64
CREST	1.00	HSPF	6.00	MODIPE	1.00	SPAW	0.48	WEAP	1.80
DANSAT	1.25	HUMUS	0.50	MultiEXCEL	0.50	SPLASH	0.25	WEHY	0.56
DHSVM	2.00	HYCYMODEL	0.75	NRM3	0.17	STARWARS	0.50	WEPP	10.8
DiCaSM	1.33	HYDROTEL	1.08	PAWS	0.33	STORE DHM	0.50	WetSpa	3.00
DITCH	0.15	IHACRES CMD	0.33	PCARES	0.08	STREAM	0.50	WLES	1.00
DORS	0.33	INFORM	1.00	PREVAH	1.83	SWAT	51.1	WMS	0.21
DWSM	0.33	InHM	1.57	PRMS	1.14	SWMM	3.50	YHyM	1.20
EROSION 3D	0.64	ISBA	1.06	PROMET	1.20	TETIS	1.17		
FEMMA	0.50	iTree-Hydro	0.50	RDI/CSEP	0.17	Thales	0.33		

Results

- Selected models from the upper 25% PI
  - 43 models
  - ~1300 papers
  - Similar pattern across years and categories
  - 3-5 hydrology papers published for every publication in other categories



	Model Name	Papers	Countries	US	
	Hydrology Models				
	DHSVM	37	5	6	
1970s →	***HBV***	**50**	**32**	**48**	Scandinavia
	HEC-HMS	50	22	15	
	HSPF	50	6	16	
	InHM	21	3	6	
	LISEM	28	14	1	
	LISFLOOD	47	19	12	
2007 →	*MGB-IPH*	10	7	0	Brazil
	MIKE-SHE	50	20	7	
	PREVAH	22	4	0	
	RHESSys	27	15	8	
	SAC-SMA	34	5	49	
	SHETRAN	34	12	0	
	SIMHYD	16	4	0	
→	***SWAT***	**50**	**24**	**19**	Texas A&M
1990s	*SWMM*	50	17	12	
→	***VIC***	**50**	**23**	**50**	U. Of Wash.
2001 →	*WaSiM-ETH*	38	9	0	Switzerland
	WATFLOOD	20	10	3	
	WEAP	42	27	26	
	WEPP	50	14	26	
	WetSpa	27	14	5	
	Total	799[1]			

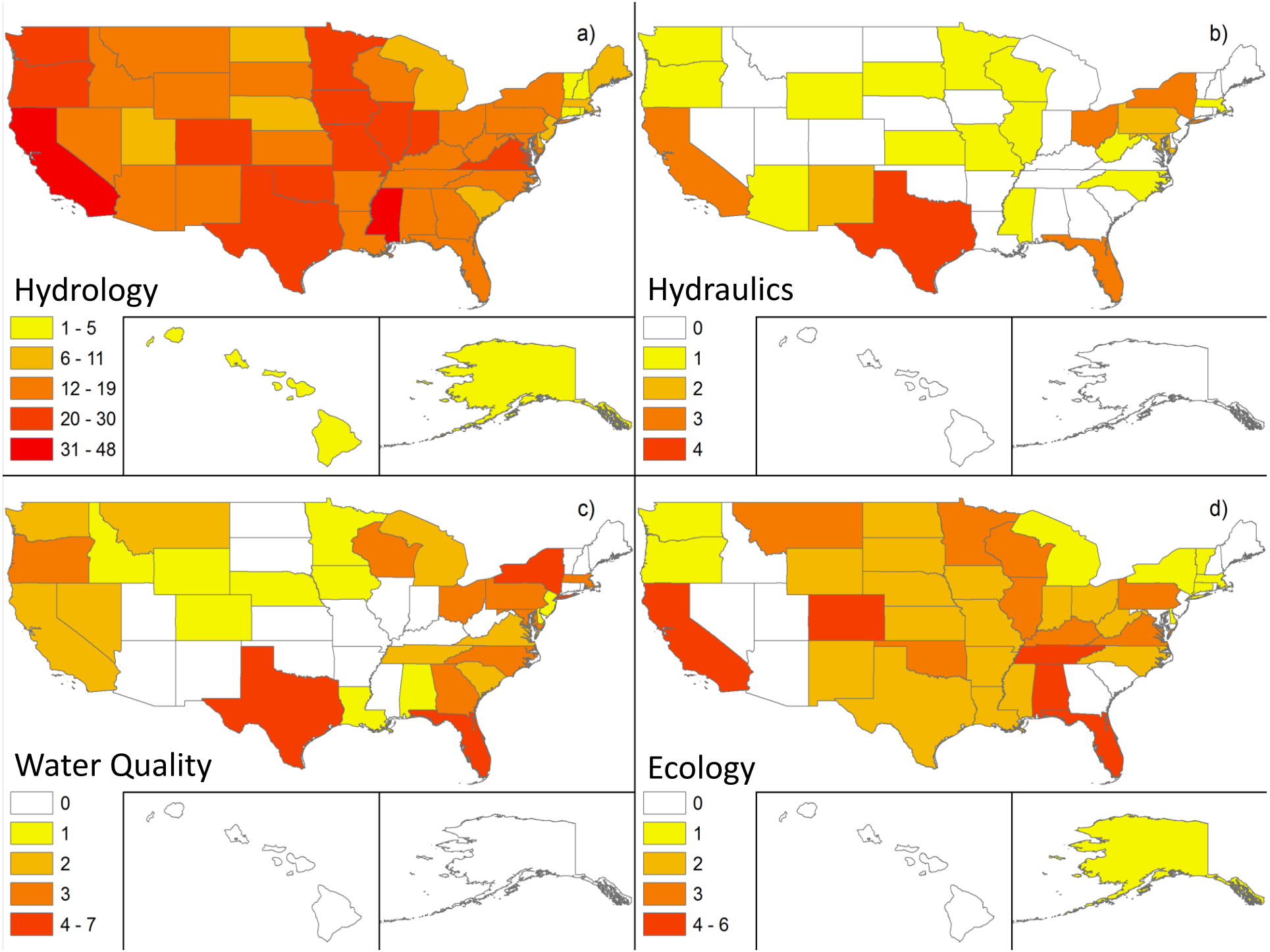


Hydrology

Hydraulics

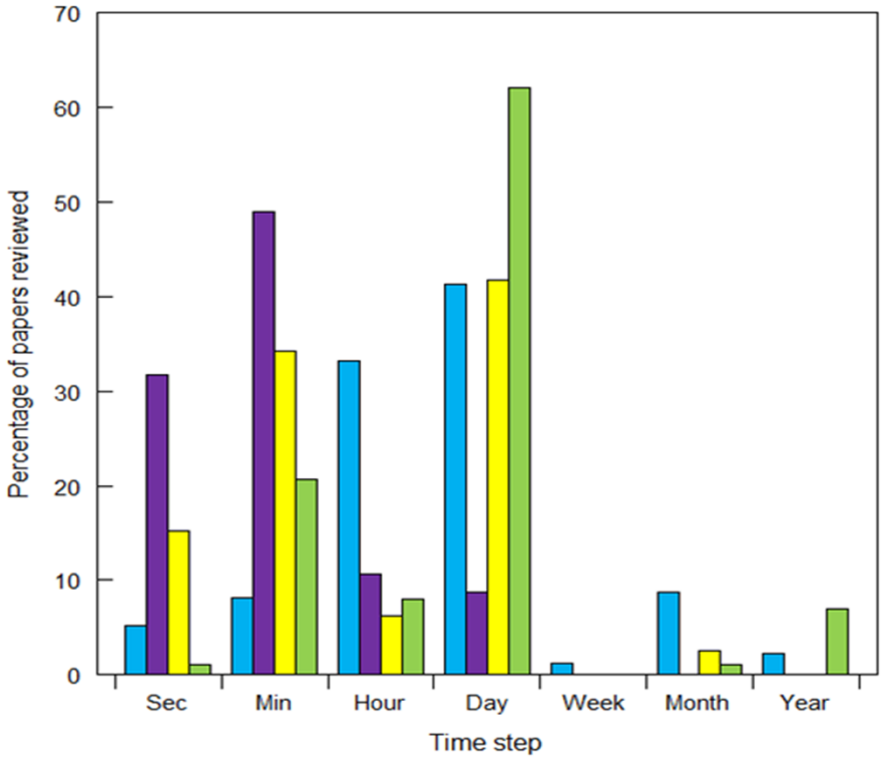
Water Quality

Ecology


a)
Hydrology
1 - 5
6 - 11
12 - 19
20 - 30
31 - 48
b)
Hydraulics
0
1
2
3
4
c)
Water Quality
0
1
2
3
4 - 7
d)
Ecology
0
1
2
3
4 - 6

Ecology Models	Papers	Countries	US	
ALFISH	4	1	1	
CAEDYM	28	14	2	
CASiMiR	4	5	0	Habitat
CENTURY	2	2	1	
FOREST-BGC	2	1	2	
LPJ	13	3	0	
ORCHIDEE	15	58	27	Carbon exchange
PHABSIM	42	12	13	Habitat
PROTECH	23	3	0	Phytoplankton
River2D	24	9	7	Habitat
Total	156			

Results



Category	Study Time Step
Second	0.001 seconds - < 1 minute
Minute	1 minute - < 1 hour
Hour	1 hour - < 1 day
Day	1 day - < 1 week
Week	1 week - < 1 month
Month	1 month - < 1 year
Year	1 year and greater

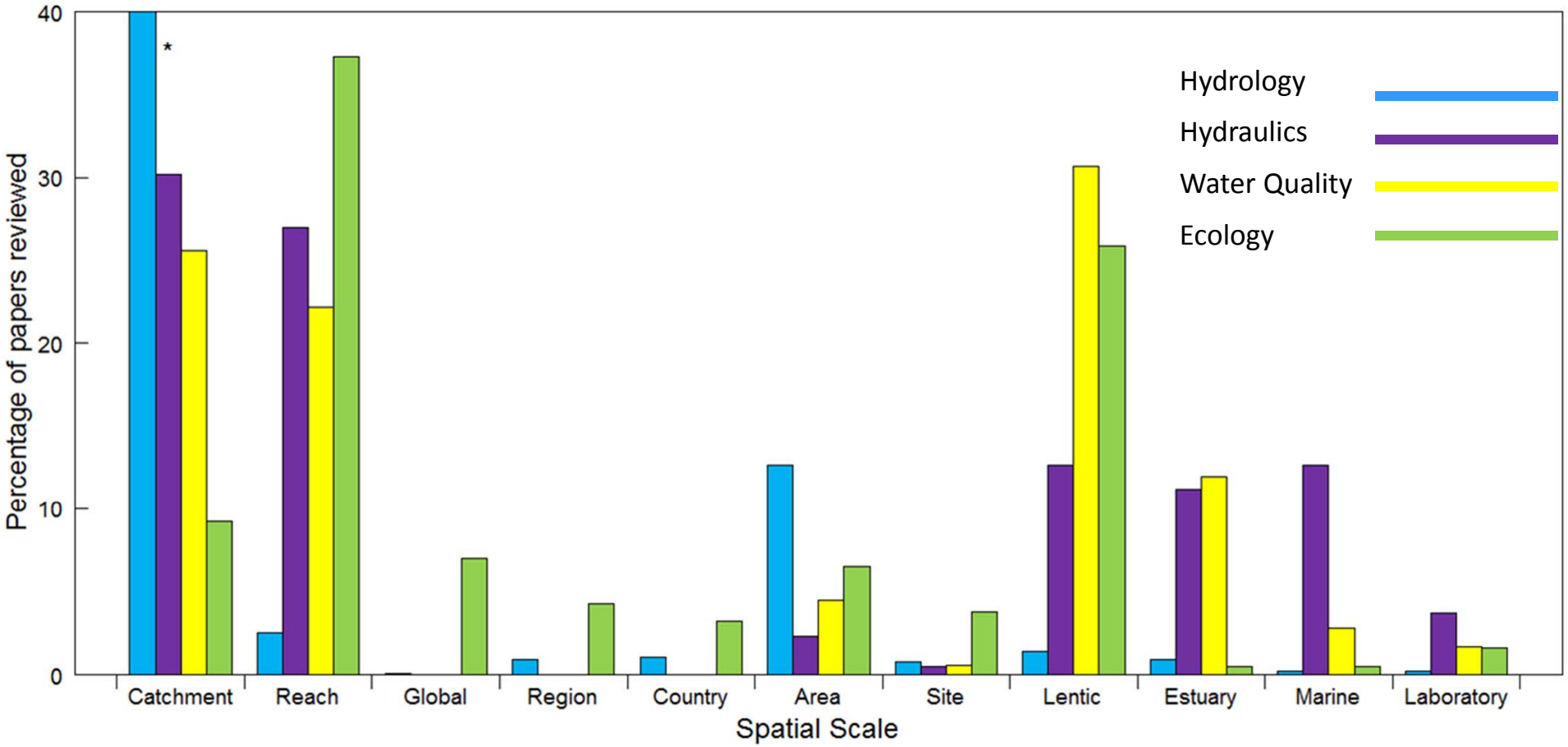
Hydrology

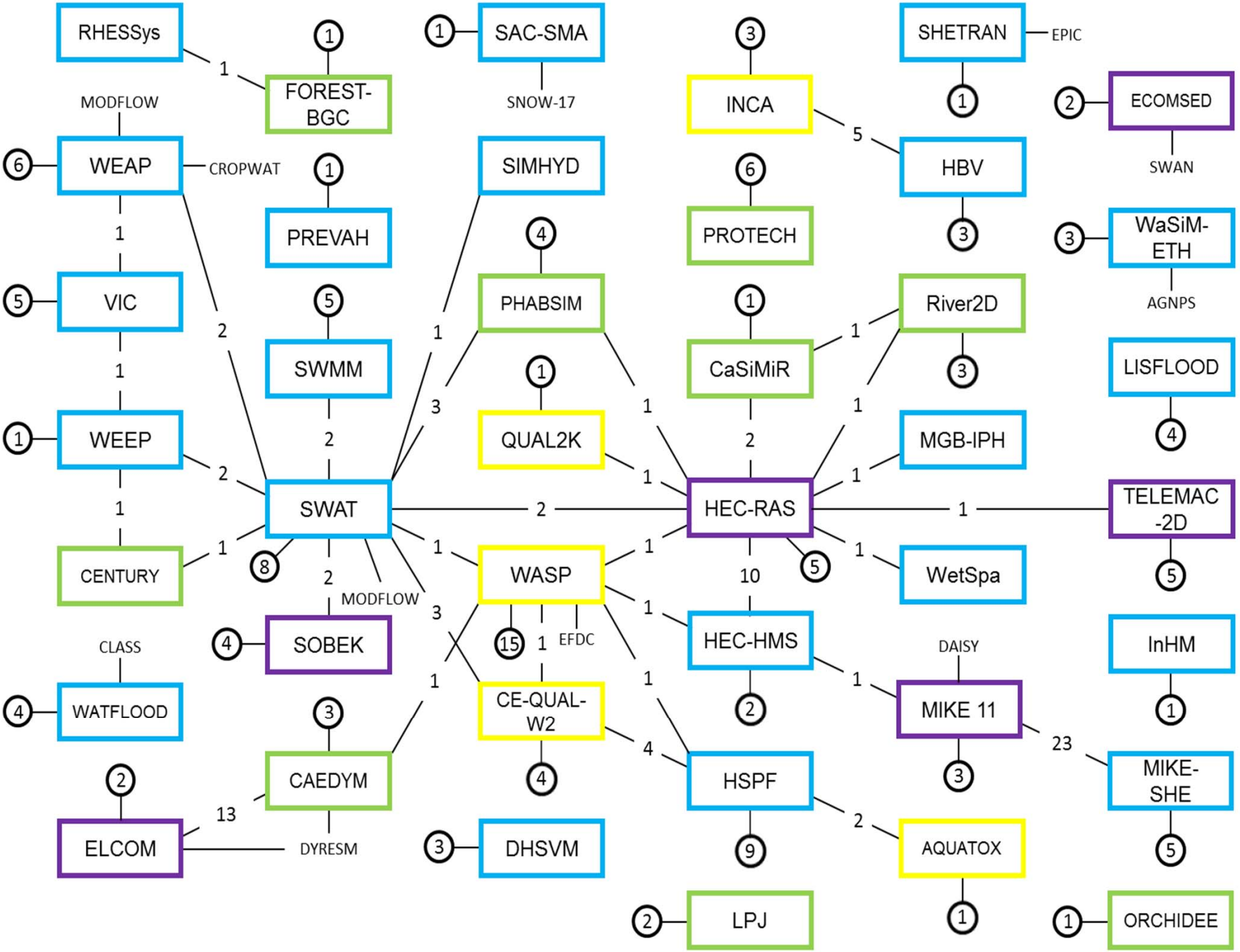
Hydraulics

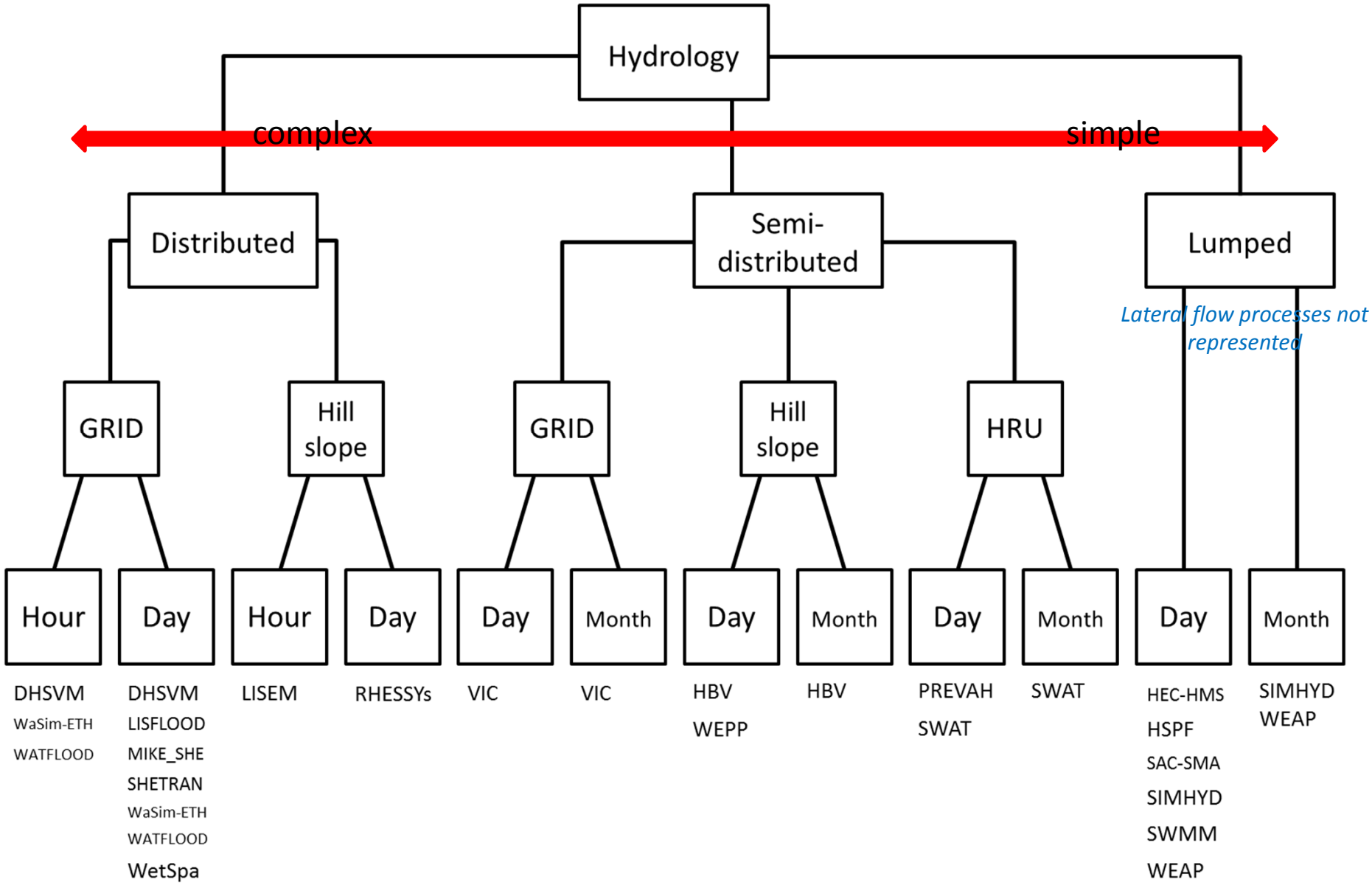
Water Quality

Ecology

Results


40
30
20
10
0
*
Percentage of papers reviewed
Hydrology
Hydraulics
Water Quality
Ecology
Catchment
Reach
Global
Region
Country
Area
Site
Lentic
Estuary
Marine
Laboratory
Spatial Scale


RHESSys
FOREST-BGC
MODFLOW
WEAP
CROPWAT
PREVAH
VIC
SWMM
WEEP
SWAT
CENTURY
SOBEK
CLASS
WATFLOOD
CAEDYM
ELCOM
DYRESM
SAC-SMA
SNOW-17
SIMHYD
PHABSIM
QUAL2K
WASP
EFDC
CE-QUAL-W2
DHSVM
INCA
PROTECH
CaSiMiR
HEC-RAS
HEC-HMS
HSPF
LPJ
SHETRAN
EPIC
HBV
River2D
MGB-IPH
WetSpa
DAISY
MIKE 11
AQUATOX
ECOMSED
SWAN
WaSiM-ETH
AGNPS
LISFLOOD
TELEMAC-2D
InHM
MIKE-SHE
ORCHIDEE


Hydrology
complex
simple
Distributed
Semi-distributed
Lumped
Lateral flow processes not represented
GRID
Hill slope
GRID
Hill slope
HRU
Hour
Day
Hour
Day
Day
Month
Day
Month
Day
Month
Day
Month
DHSVM
WaSim-ETH
WATFLOOD
DHSVM
LISFLOOD
MIKE_SHE
SHETRAN
WaSim-ETH
WATFLOOD
WetSpa
LISEM
RHESSYs
VIC
VIC
HBV
WEPP
HBV
PREVAH
SWAT
SWAT
HEC-HMS
HSPF
SAC-SMA
SIMHYD
SWMM
WEAP
SIMHYD
WEAP

Conclusions

- Hydrology models are the most common (flooding, land-use change)
- SWAT, HEC-RAS, and WASP currently are the most flexible models for integration
- Other models linked together often (e.g., MIKE 11 and MIKE-SHE)
- Model renaming by investigators increases difficulty (e.g., Protech)
- Model applications greatest in arid regions and locations with cold-water fisheries
- Over 50% of papers did not explicitly state the model time step (includes those modeling Q)
- Some models very specialized (e.g., ELCOM in lentic systems) whereas others more flexible
- Tradeoff between scale and cost/complexity drive model choice

Acknowledgements

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- Chris Zou, Derek Ryder, Dakota McNeil, Dawson McNeil