Journal: Fishes, Special Issue: Effect of Climate Change on Salmonid Fishes in Rivers

Supplement S1: *A comprehensive review of the impacts of climate change on salmon: strengths and weaknesses of the literature by life stage*

Supporting information for:
A comprehensive review of the impacts of climate change on salmon: strengths and weaknesses of the literature by life stage

Lisa G. Crozier[1] and J. E. Siegel[2]

1. *Northwest Fisheries Science Center, NOAA Fisheries*
2. *Ocean Associates, Inc. Under contract to NWFSC. Current address: PACE Engineers, Inc. 3501 Colby Ave Suite 101, Everett, WA 98201*

Key words: *anadromous fish; ecological responses to climate change; future projections; global change; ocean; freshwater*

SUPPLEMENT S1 CONTENTS

Supplement S1: Quantitative analysis of categories across the entire database

Biological driver and response processes

Across our dataset as a whole, demographics was the most commonly studied response process (47%), followed by physiology (35%) and dispersal (i.e., migration behavior and habitat use, 24%, Figure S1, right). Among driver processes, environmental conditions were incorporated into the majority of studies (79%), reflecting their importance in our search criteria, followed by species interactions (33%) and management (24%) (Figure S1, left). Evolutionary dynamics were the least-studied process. Nonetheless, 140 papers (8%) provided evidence on interactions between environmental conditions and genetic characteristics, with an additional 59 papers addressing some sort of adaptation in response to climate (combined, 11%).

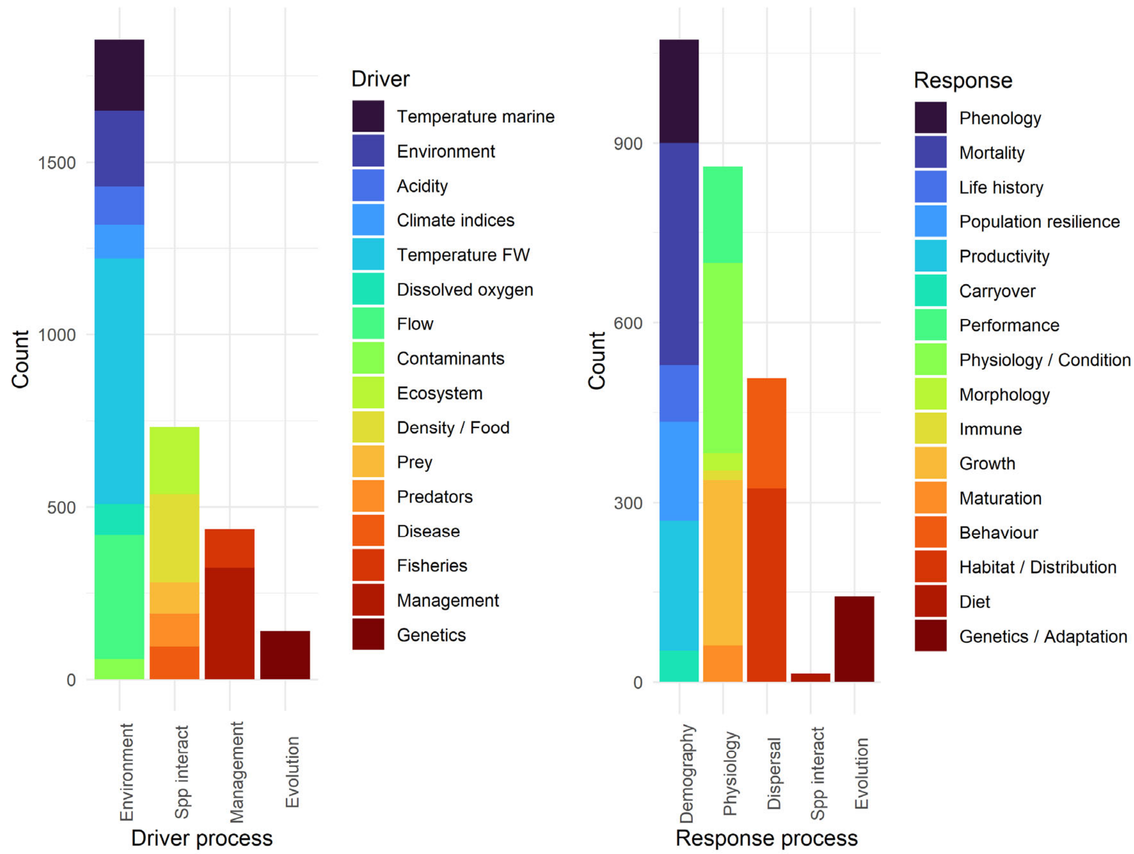


Figure S1. Count of papers within each *driver process* (left) and *response process* (right), showing the proportion of individual keywords (colors) that fell into each label (x-axis)**.**

Study type

Across the database as a whole, the majority of studies contained a field or remote sensing component (57%) followed by lab/experimental studies (21%), modeling studies (16%), and reviews or meta-analyses (11%). Note that studies were only given the modeling label if the model was a focus of the paper (e.g., methods paper), the model was used for future projections, or modeling was mechanistic or theoretical. Statistical correlative modeling papers, which were common, were not given this label. Theoretical/opinion papers comprised only 5% of our dataset, and papers projecting impacts of climate change directly on salmon only 4%. We also reviewed a handful of papers that predicted relevant ecosystem and physical impacts from climate change, with each comprising 2%, which is just a fraction of that larger literature. However, the frequency of different study types varied by life stage, reflecting the areas of research and the tractability of different types of research in different habitats.

Life stage

We compared the relative frequency of papers studying different life stages. The juvenile rearing stages in freshwater (33%) and saltwater (28%) were the stages that were addressed most commonly. Migration stages were highlighted in 10% and 14% of the papers for downstream and upstream directions respectively. Egg, spawning and population level analyses constituted 6%, 7%, and 9% of the database respectively. Response metrics were also studied at different frequencies by life stage (Figure S2).

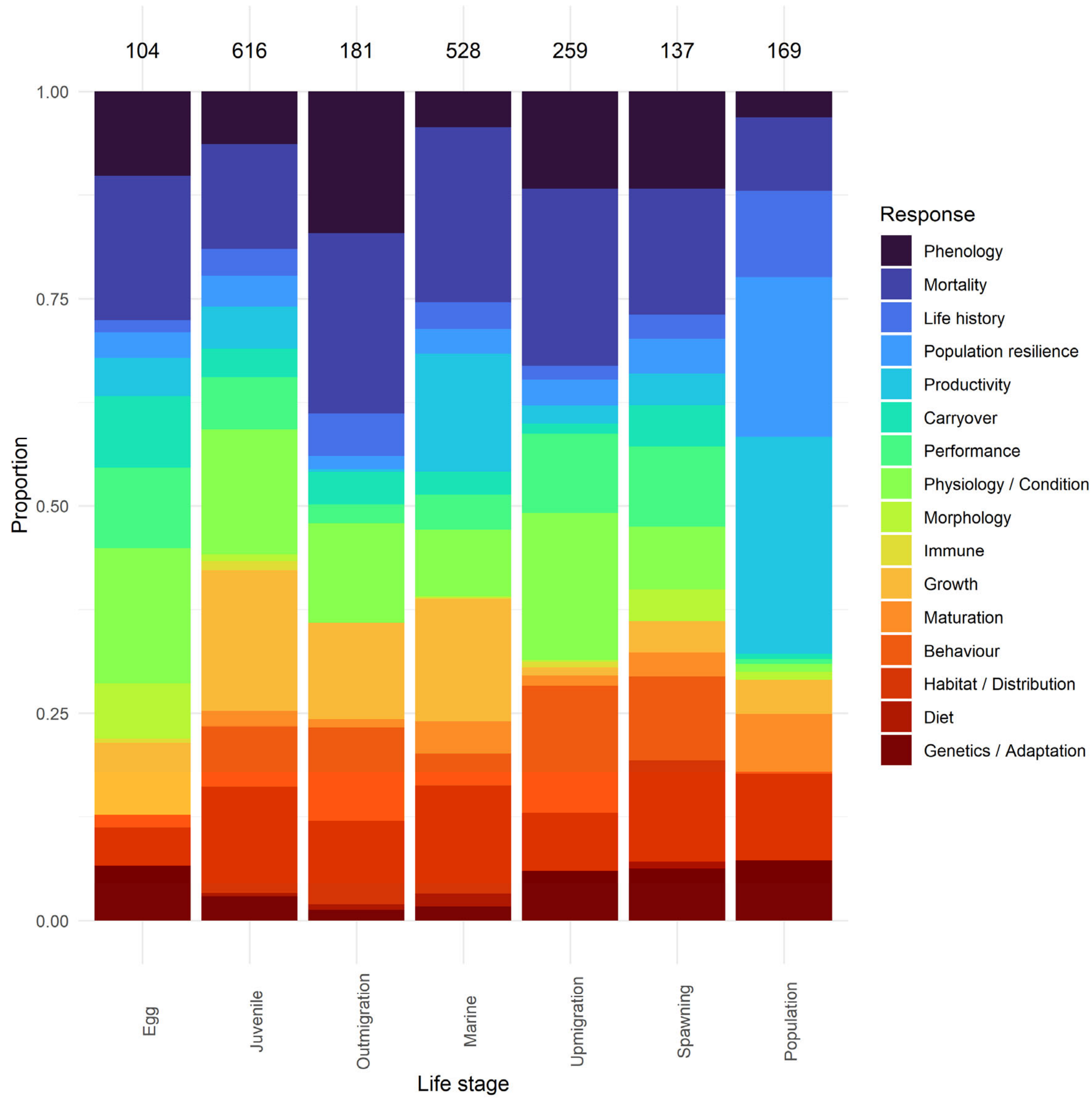


Figure S2. Relative proportion of papers in each life stage that involved different response metrics. The absolute number of papers represented in each column is at the top. The juvenile stage refers to the freshwater rearing portion of the life cycle.

Region and species

Our focal region was the PNW, especially the Columbia River Basin, and we found 483 papers within this region (Figure 3). The marine migration of PNW populations overlaps with that of populations from California, British Columbia and Alaska, as well as the Far East. These areas also constitute the historical range of our focal species, and thus are also well represented in our study (569 unique papers on the west coast of North America outside the Pacific Northwest, and 48 from the Far East regions of Russia and Japan). Pacific salmon have been introduced or used in aquaculture in many other locations, and studies from these sites can reveal how salmon respond and adapt to new environmental conditions (35 papers were from South America, other parts of Asia, Africa or Australia/New Zealand).

Chinook (*O. tshawytscha*) and steelhead (*O. mykiss*) were the most common species studied in the PNW and California, whereas sockeye salmon (*O. nerka*) was predominant in British Columbia and Alaska. Atlantic salmon and brown trout (*Salmo trutta*) were more common in Europe.

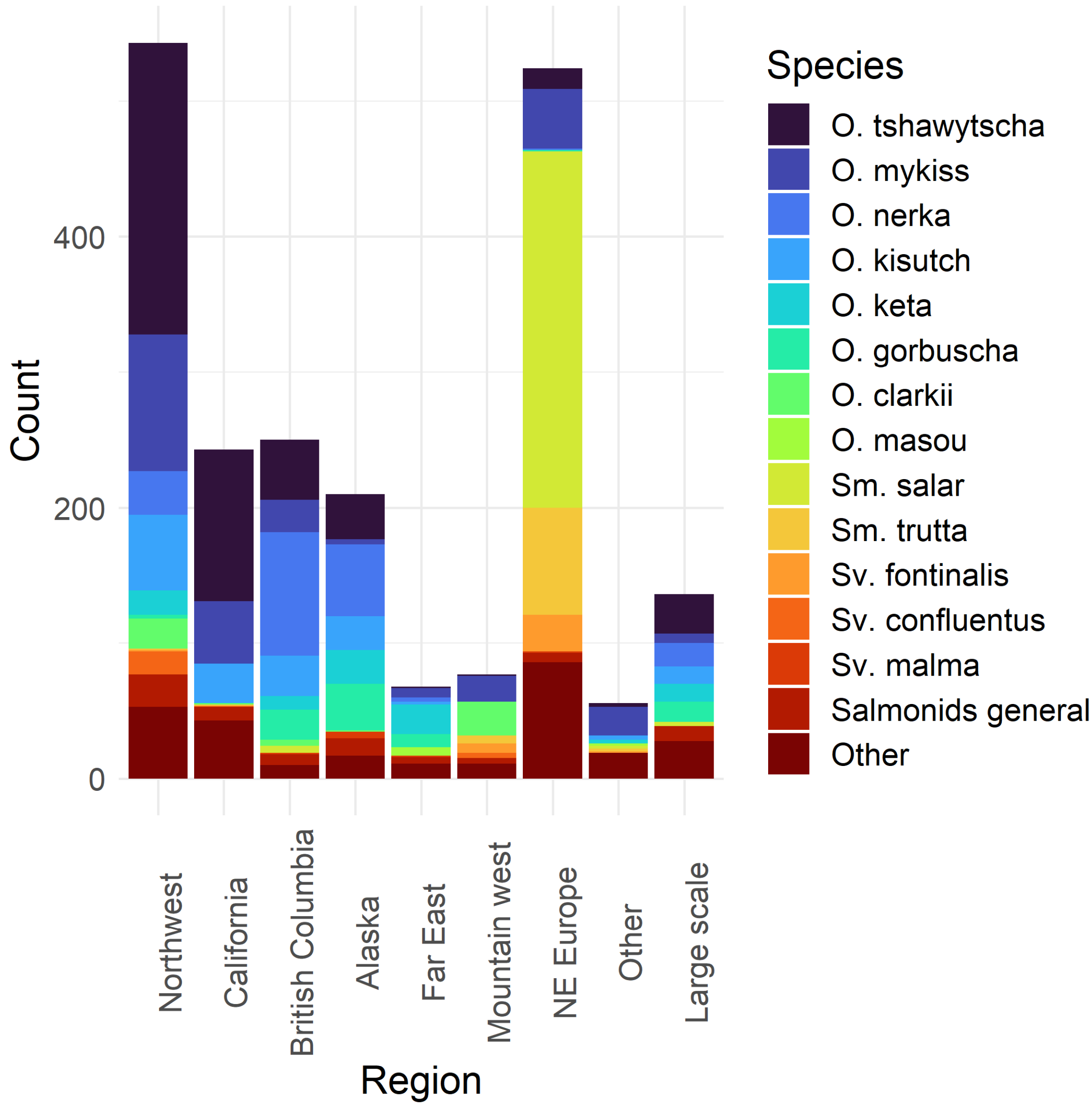


Figure 3. Count of species label designations by region for reviewed papers. Note that individual papers may address multiple species, so the total count reflects the number of times individual species were mentioned within a region, not the number of unique papers.

Atlantic salmon and other trout species also provide analogous case studies for Pacific salmon in many situations, explaining the high number of papers from eastern North America (179), Europe (299), and interior rivers of the Rocky Mountains (53).

Numerous papers (118, 6%) spanned multiple regions, especially oceanographic regions such as the North Pacific or California Current. Counts of papers for all labels are shown in Supplement S1: Table S2. Note that because a single paper can have multiple labels within each category, the number of unique papers is not necessarily the sum of the number for each label.

O. mykiss and *S. salar* were represented somewhat more than other species when looking at studies of evolutionary process (these species constituted 14% of studies that focused on evolution, compared with the two species' representation in the database overall, 11%). Rainbow trout (*O. mykiss*) and Atlantic salmon are intensively cultivated and therefore often studied within the context of genetic engineering, while landlocked redband trout (*O. mykiss*) displays especially extensive local climate adaptation, facilitating mapping between genetic characteristics and environmental gradients.

Study duration

The duration of studies in our database was characterized largely by either very short (1 year or less: 55%, 2-5 years: 18%) or very long (over 10 years: 25%) study periods. Of the long study periods, most capitalized on long environmental and population time series, and were more frequent for marine stage or whole life cycle analyses (Figure 4). A few papers that covered long time series also tested specific hypotheses with short-term experiments (4 papers). One unusual paper explored a 23-year history of columnaris disease in fish farms (Pulkkinen et al. 2010).

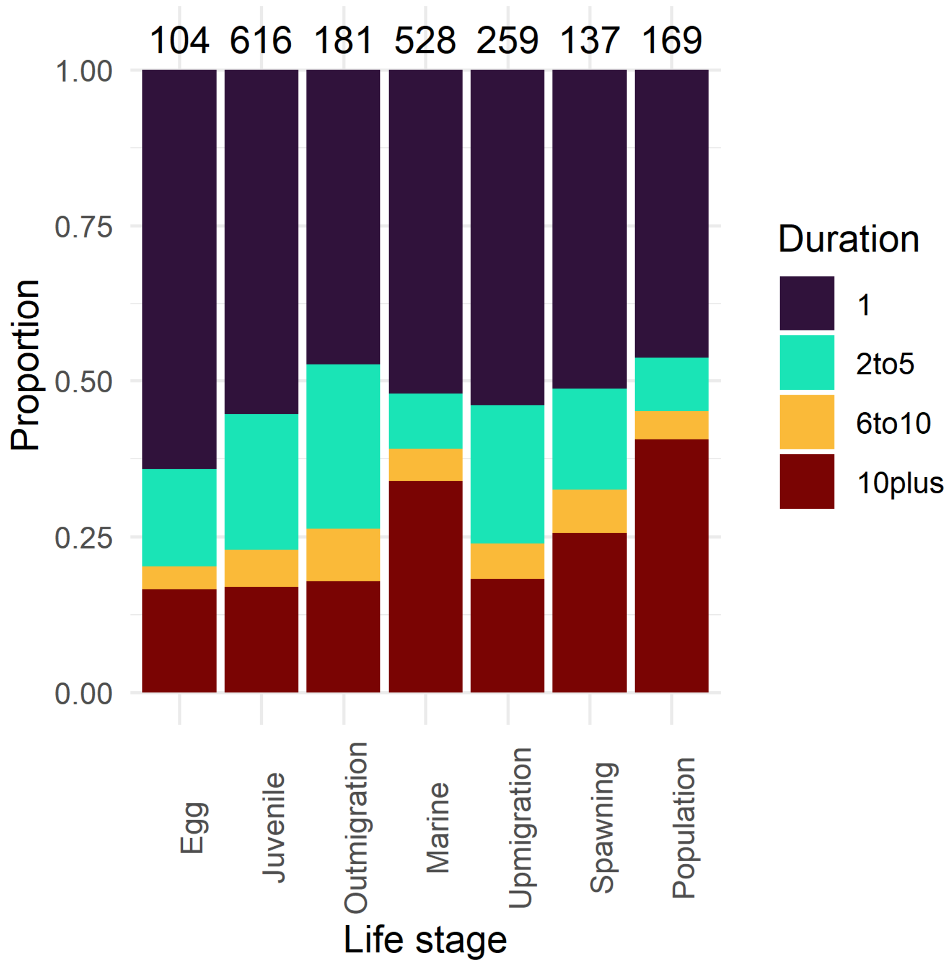


Figure 4. Proportion of papers within each life stage that spanned the designated study duration, in years. The absolution number of papers represented is the top of each column.

Long time-series are particularly important for understanding salmon responses to climate change because long-term climate trends may differ from those resulting from short-term annual or decadal variation. For example, using sediment evidence from the Holocene, Finney et al. (2010) found that fish population abundance often tracked decadal cycles in ocean conditions over centuries. Indices such as the El Niño Southern Oscillation and the Pacific Decadal Oscillation reflect distinct physical and ecological regime shifts, which are often associated with changes in salmon marine survival rates. Detangling long-term trends due to climate change, and the emergence of novel physical and ecological conditions, in the sense that not only individual conditions, but combinations of conditions that have not been exhibited before (Smith et al. 2022), is an important component of future projections.

Literature Cited

Finney, B. P., J. Alheit, K. C. Emeis, D. B. Field, D. Gutierrez, and U. Struck. 2010. Paleoecological studies on variability in marine fish populations: A long-term perspective on the impacts of climatic change on marine ecosystems. Journal of Marine Systems **79**:316-326.

Pulkkinen, K., L. R. Suomalainen, A. F. Read, D. Ebert, P. Rintamaki, and E. T. Valtonen. 2010. Intensive fish farming and the evolution of pathogen virulence: The case of columnaris disease in Finland. Proceedings of the Royal Society B-Biological Sciences **277**:593-600.

Smith, J. A., M. Pozo Buil, J. Fiechter, D. Tommasi, and M. G. Jacox. 2022. Projected novelty in the climate envelope of the California Current at multiple spatial-temporal scales. PLOS Climate **1**:e0000022.

Table S1: Description of the criteria used to assign each label

List of labels within categories assigned to all papers, with brief definition of labels. Papers were assigned multiple labels within a category, as appropriate to papers covering multiple species, life stages, etc.

Category/labels	**Description**
Species	
Oncorhynchus clarkii	Cutthroat trout
Oncorhynchus gorbuscha	Pink salmon
Oncorhynchus keta	Chum salmon
Oncorhynchus kisutch	Coho salmon
Oncorhynchus masou	Masu salmon
Oncorhynchus mykiss	Rainbow trout/steelhead
Oncorhynchus nerka	Sockeye salmon
Oncorhynchus tshawytscha	Chinook salmon
Salmo salar	Atlantic salmon
Salvelinus confluentus	Bull trout
Salvelinus fontinalis	Brook trout
Salvelinus malma	Dolly Varden
Salmo trutta	Brown trout
Other fish	Other fish species
Other species	Other non-fish species
General	Non-specific species deemed relevant
Life Stage	
Egg	Egg incubation through emergence
Juvenile	Freshwater juvenile rearing
Juvenile migration	Juvenile migration to the ocean as smolt
Marine	Marine rearing, growth, and survival
Adult migration	Adult spawning migration, including pre-spawn holding
Spawning	Spawning
Population	Productivity, demographic trends, or population resiliency—any stage
Evolution	Explicit use of evolutionary methods or perspective,
Freshwater habitat	Freshwater habitat (may not be specific to a life stage)
General	Issues not specific to salmon or life stage, but determined to be relevant
Region	
Africa	Populations from Africa
Alaska	Populations from Alaska
Australia New Zealand	Populations from Australia and New Zealand
British Columbia	Populations from British Columbia, Canada
California	Populations from California, USA
Asia other	Populations from countries in Asia other than Japan and Russia
East North America	Populations from Canada and the U.S. east of the Rocky Mountains
Europe	Populations from Europe
Japan	Populations from Japan
Largescale	Encompassing three or more regions (e.g., ocean or large-scale climate)
Mountain west	Populations from the Rocky Mountain or interior basins of U.S./Canada
Northwest	Populations from Northwest region of the U.S.
Russia	Populations from Russia
South America	Populations from South America

Table S1: Continued.

Category/labels	Description
Sub-region	
Alaska SE	Southeast Alaska from Yakutat to southern tip of Alaskan panhandle
Alaska S	South Alaska draining into Gulf of Alaska from Aleutians to Yakutat
Alaska W	Western and central Alaska draining into the Bering Sea or the Arctic
California N	Northern coastal California from San Francisco Bay to Oregon border
California S	Southern coastal California from Mexican border to San Francisco Bay
California CV	Central Valley CA from San Joaquin and Sacramento Basins to SF Bay
British Columbia non Fraser	Areas of British of Columbia outside Fraser River watershed
Northwest Coastal	Coastal Oregon and Washington State
British Columbia Fraser	Areas of British of Columbia, Canada within Fraser River watershed
Northwest Columbia	Columbia River watershed, U.S. Pacific Northwest
Northwest Puget Sound	Puget Sound watershed, Washington State
Study type	
Field remote sensing	Data collected in the field and/or by remote transmitted data
Lab experimental	Lab experiments or field experimental designs
Model	Model as focus (e.g., methods, life cycle models) or those used to make future projections. Statistical models describing relationships excluded
Projections ecosystem	Climate change projections for ecosystems deemed relevant to salmon but not specifically projecting salmon
Projections physical	Physical climate change projections deemed relevant to salmon
Projections salmon	Climate change projections for salmon populations
Review meta-analysis	Reviews and meta-analyses
Theory/opinion	Theoretical and opinion
Study duration	
1	Study or time-series of 1 year or less
2-5	Study or time-series of 2-5 years
6-10	Study or time-series of 6-10 years
10+	Study or time-series of over 10 years
NA	No applicable study period or time-series (often theoretical)

Table S2: The number of papers assigned to each label across the database as a whole and within each life stage.

Counts of papers that received the labels listed in Table S1. "All" column shows the number and proportion of unique papers with the label in the corresponding row from all papers in the database. Subsequent columns show the number of papers from the "All" column that were also assigned a life history or population label. Note that a single paper could be assigned multiple labels if, for example, multiple regions or life stages were explicitly addressed in that paper.

	All				Juvenile		Adult		
Category/label	N	(%)	Egg	Juvenile	migrate	Marine	migrate	Spawn	Population
All	1853	100	104	616	181	528	259	137	169
Process driver									
Environment	1459	79	92	529	151	382	203	102	114
Spp. interactions	602	33	9	213	54	275	57	26	33
Management	436	24	12	122	49	94	81	32	62
Evolution	140	8	16	33	6	13	21	16	23
Process response									
Demography	861	47	73	259	120	244	150	83	143
Physiology	645	35	54	302	68	158	95	50	32
Dispersal	451	24	11	167	60	97	77	48	34
Evolution	143	8	13	28	4	11	25	15	23
Spp. interactions	14	1	0	4	2	10	0	2	0
Driver									
Freshwater temp	711	38	63	328	59	56	144	62	56
Habitat	444	24	20	169	58	36	48	36	42
Flow	361	20	30	154	45	20	67	39	50
Management	323	17	10	107	42	55	54	25	43
Density food	256	14	4	122	25	107	6	15	18
Environment	218	12	7	50	28	104	10	6	19
Temp marine	207	11	2	14	20	170	10	4	24
Ecosystem	195	11	1	23	5	141	2	2	7
Genetics	140	8	16	33	6	13	21	16	23
Methods	119	6	4	21	12	30	12	8	13
Fisheries	113	6	0	6	1	57	30	5	22
Acidity	113	6	2	14	3	94	2	0	1
Climate indices	97	5	3	10	5	73	6	2	20
Predators	96	5	0	27	16	49	11	3	3
Disease	94	5	3	40	6	25	41	7	0
Prey	91	5	1	30	13	59	0	3	0
Dissolved oxygen	90	5	12	36	10	26	9	9	2
Contaminants	58	3	2	29	8	15	16	3	2
Restoration	53	3	4	14	7	1	3	4	7
Invasive species	32	2	0	22	2	0	1	0	5

Table S2. Continued.

Category/label	All N	All (%)	Egg	Juvenile	Juvenile migrate	Marine	Adult migrate	Spawn	Population
Response									
Mortality	371	20	34	121	67	136	89	36	28
Habitat distribute	323	17	9	122	31	84	29	29	33
Physiol/condition	318	17	32	145	37	52	74	18	3
Growth	276	15	17	162	36	95	4	9	13
Productivity	217	13	9	49	1	92	9	9	83
Behavior	184	10	3	70	35	25	64	24	1
Phenology	172	9	20	61	53	28	49	28	10
Pop. resilience	166	9	6	35	5	19	13	10	61
Performance	161	9	19	60	7	27	40	23	2
Genetic/adapt	143	8	13	28	4	11	25	15	23
Life history	94	5	3	31	16	21	7	7	33
Maturation	61	3	0	18	3	25	5	7	22
Carryover	52	3	17	33	12	18	5	12	2
Morphology	29	2	13	8	0	1	1	9	3
Immune	16	1	1	10	0	1	3	0	0
Livelihood	14	1	0	0	0	3	0	0	0
Diet	14	1	0	4	2	10	0	2	0
Study type									
Field remote sense	1052	57	41	345	133	322	166	94	102
Lab experimental	379	21	55	195	33	69	60	24	3
Model	302	16	17	88	23	84	31	21	53
Meta-analysis	210	11	8	35	7	78	23	8	22
Theory/opinion	93	5	0	14	4	24	6	1	14
Projection salmon	68	4	6	28	6	5	12	8	19
Projection physical	39	2	0	3	1	14	0	1	0
Projection ecosys	30	2	0	2	0	24	0	0	0
Study duration									
1 year	1026	6	70	362	101	338	151	82	81
10 plus years	457	3	18	111	38	220	51	41	71
2-5 years	324	2	17	142	56	57	62	26	15
6-10 years	115	1	4	39	18	34	16	11	8

Table S2. Continued.

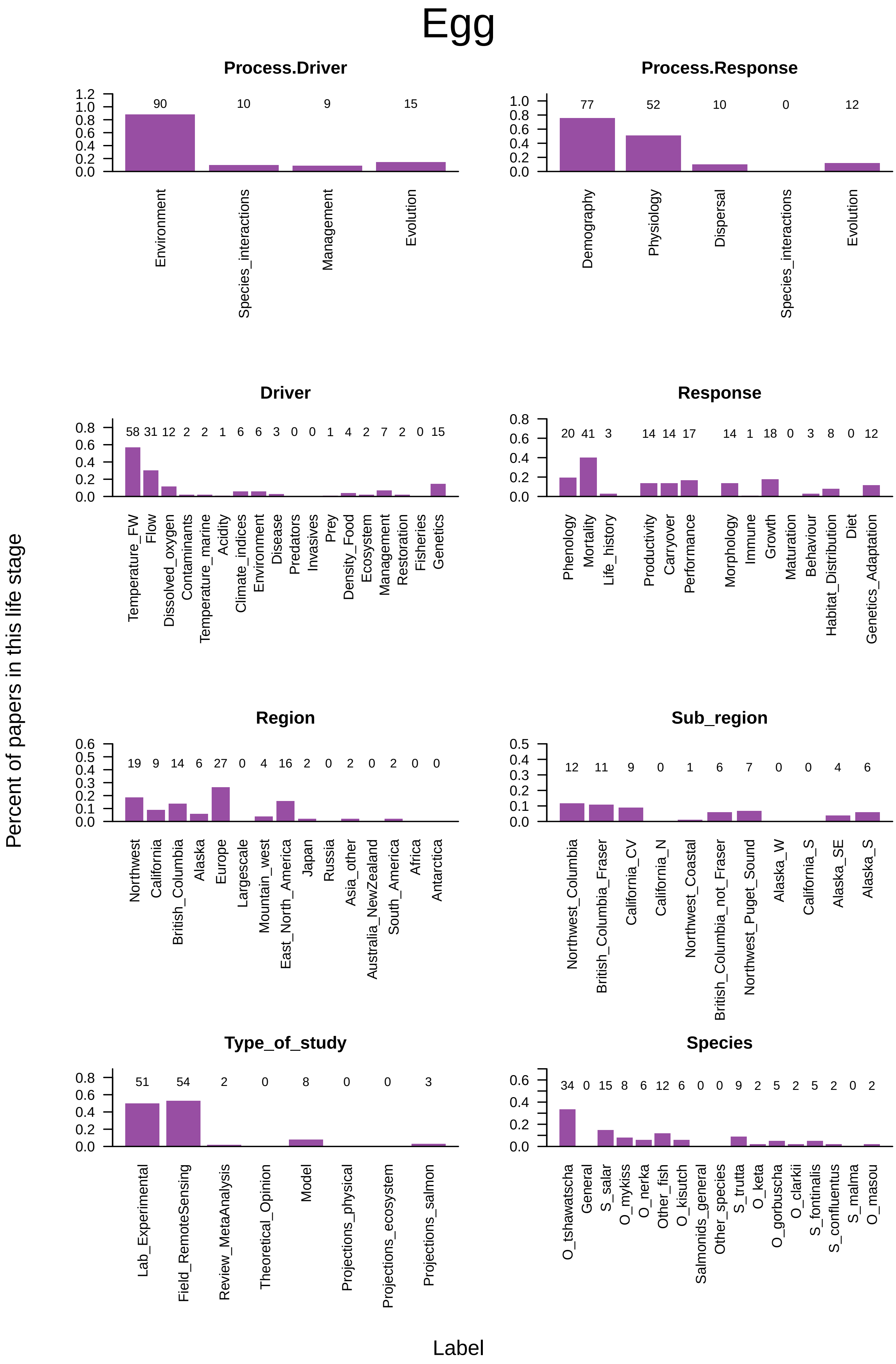
Category/label	All N	All (%)	Egg	Juvenile	Juvenile migrate	Marine	Adult migrate	Spawn	Population
Region									
Northwest	483	26	18	155	55	133	75	48	39
Europe	299	16	22	130	40	76	27	15	40
California	237	13	11	98	36	65	25	13	18
Brit Columbia	205	11	14	51	21	70	57	15	14
East N America	179	10	15	70	13	46	24	13	14
Alaska	149	8	6	28	6	61	27	18	16
Largescale	118	6	0	6	1	93	2	1	12
Mountain west	53	3	4	25	0	0	4	1	8
Japan	34	2	2	10	4	17	4	1	1
Asia other	22	1	2	9	4	3	2	1	2
Australia/NZ	21	1	1	6	1	12	2	2	0
Russia	15	1	0	0	0	10	1	0	3
South America	10	1	2	2	0	2	0	1	0
Antarctica	2	<1	0	0	0	2	0	0	0
Africa	1	<1	0	0	0	0	0	0	0
Sub-region									
NW Columbia	304	16	12	113	38	46	61	35	24
BC Fraser	110	6	10	28	9	19	48	11	7
NW Coastal	106	6	1	18	5	54	8	5	10
California N	106	6	0	36	7	43	17	6	6
California CV	105	6	10	54	27	14	10	8	10
BC not Fraser	90	5	6	21	11	46	9	6	7
NW Puget Sound	86	5	5	26	12	29	8	10	11
Alaska W	77	4	2	8	1	33	18	11	9
Alaska S	77	4	4	20	5	27	11	8	11
California S	54	3	1	11	4	32	2	1	2
Alaska SE	48	3	2	10	3	19	11	8	4

Table S2. Continued.

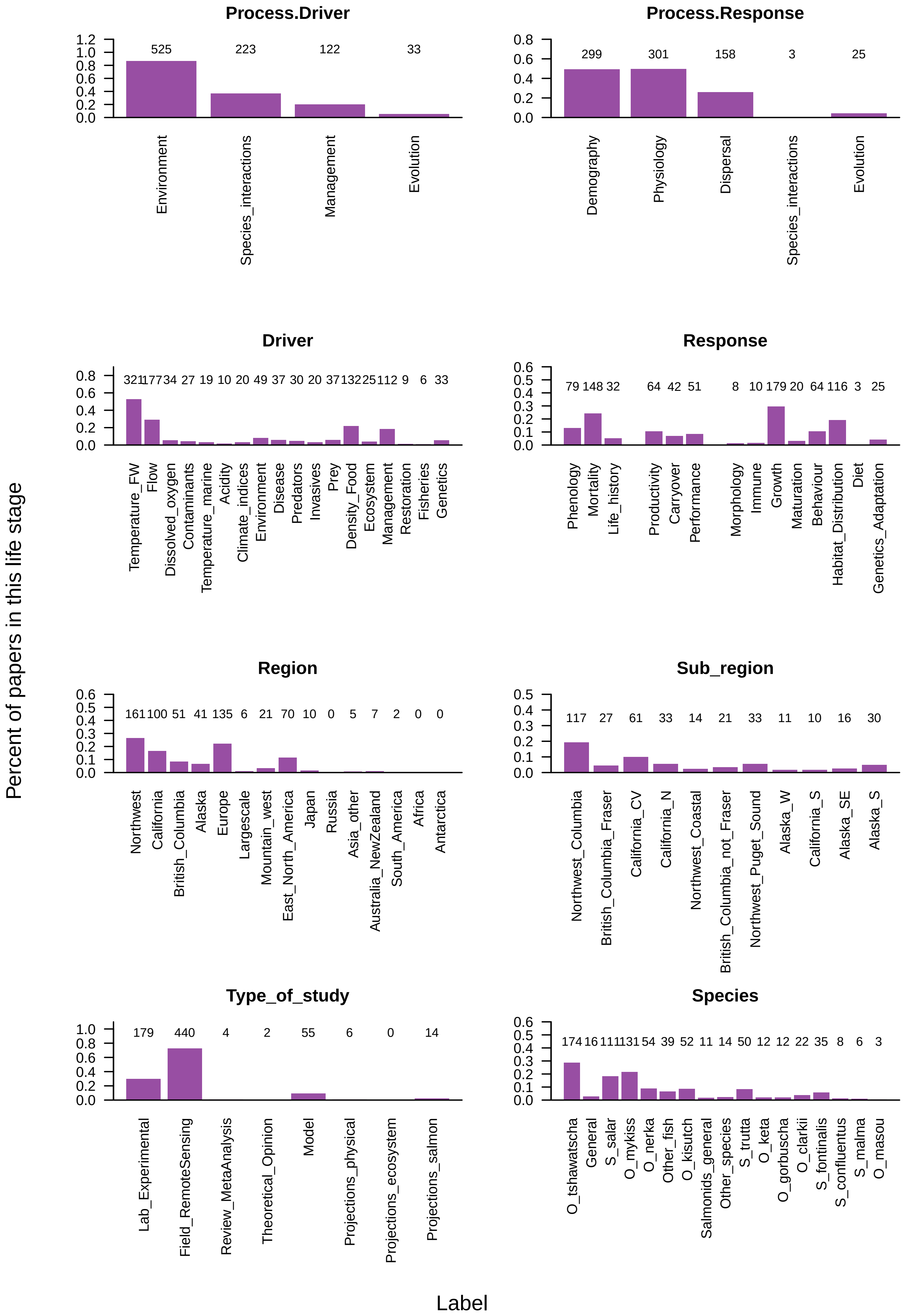
Category/label	All N	All (%)	Egg	Juvenile	Juvenile migrate	Marine	Adult migrate	Spawn	Population
Species									
O. tshawytscha	425	23	35	154	64	118	77	51	42
General	286	15	5	40	8	103	14	5	14
Salmo salar	267	14	13	104	44	76	28	15	31
O. mykiss	261	14	10	131	33	26	45	15	21
O. nerka	179	10	8	40	16	52	64	21	20
Other fish	160	9	12	41	5	72	13	10	17
O. kisutch	151	8	6	54	14	36	25	14	20
Salmonids gen	114	6	5	32	7	19	13	6	11
Other species	107	6	0	17	1	79	4	0	1
Salmo trutta	91	5	9	46	7	4	15	9	13
O. keta	79	4	1	10	10	43	13	8	9
O, gorbuscha	73	4	3	11	5	41	17	10	5
O. clarkii	55	3	2	25	1	0	4	4	17
Sal. fontinalis	38	2	3	31	0	0	1	1	3
Sal confluentus	22	1	2	9	1	0	1	2	4
Sal malma	8	<1	0	4	2	1	3	2	2
O. masou	8	<1	2	4	1	0	0	1	1

Figure S1 Panel plots for each life stage and label, showing the number and percent of papers in each label.

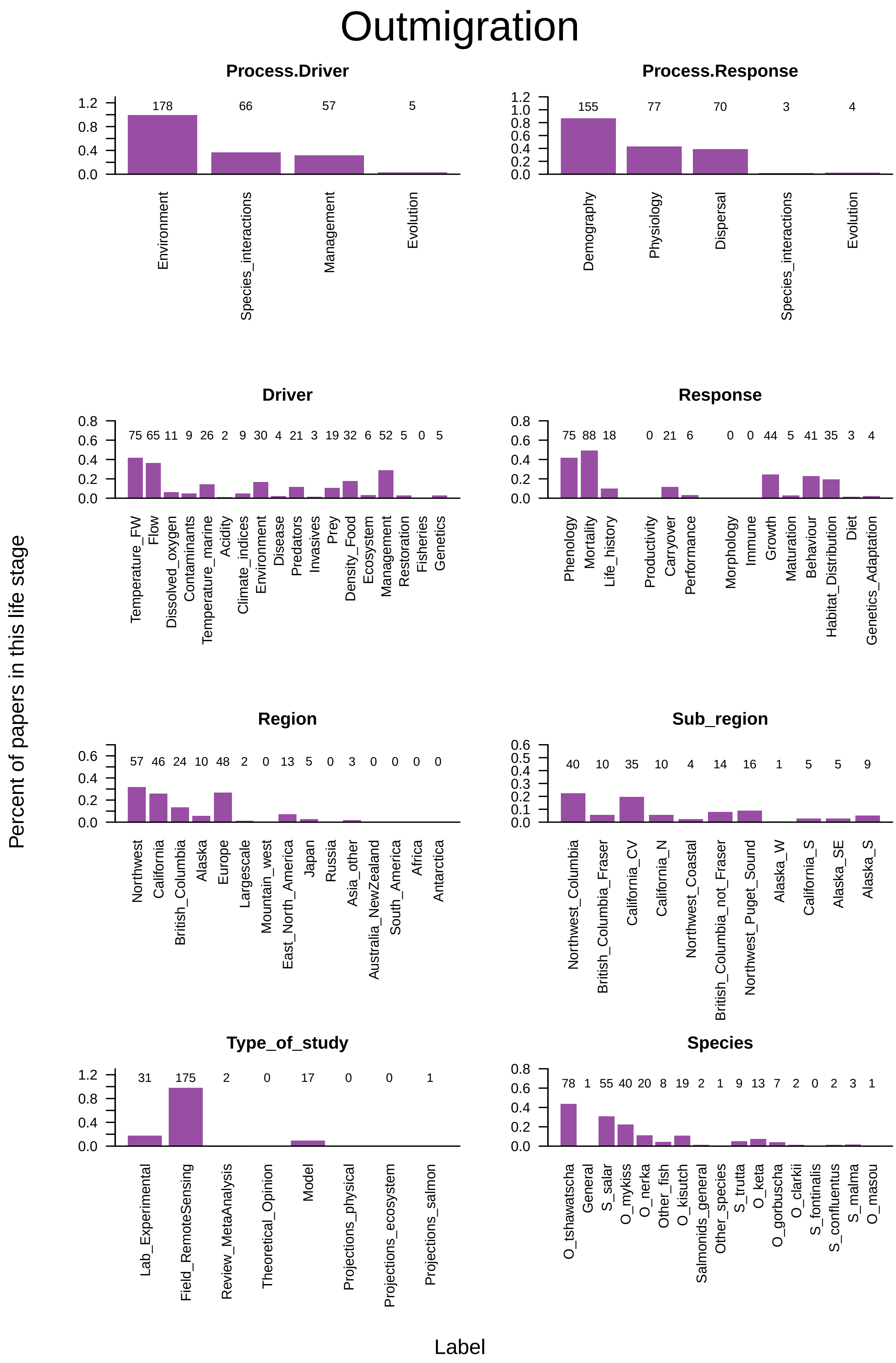
Caption: These more detailed barcharts show the relative frequency of each label within all categories for each life stage. The y-axis shows the proportion of all papers within the life stage that fell in each bin, and the absolute number of papers in each bin are shown above each column.


Egg
Percent of papers in this life stage
Label
Process.Driver
90 10 9 15
Environment
Species_interactions
Management
Evolution
Process.Response
77 52 10 0 12
Demography
Physiology
Dispersal
Species_interactions
Evolution
Driver
58 31 12 2 2 1 6 6 3 0 0 1 4 2 7 2 0 15
Temperature_FW
Flow
Dissolved_oxygen
Contaminants
Temperature_marine
Acidity
Climate_indices
Environment
Disease
Predators
Invasives
Prey
Density_Food
Ecosystem
Management
Restoration
Fisheries
Genetics
Response
20 41 3 14 14 17 14 1 18 0 3 8 0 12
Phenology
Mortality
Life_history
Productivity
Carryover
Performance
Morphology
Immune
Growth
Maturation
Behaviour
Habitat_Distribution
Diet
Genetics_Adaptation
Region
19 9 14 6 27 0 4 16 2 0 2 0 2 0 0
Northwest
California
British_Columbia
Alaska
Europe
Largescale
Mountain_west
East_North_America
Japan
Russia
Asia_other
Australia_NewZealand
South_America
Africa
Antarctica
Sub_region
12 11 9 0 1 6 7 0 0 4 6
Northwest_Columbia
British_Columbia_Fraser
California_CV
California_N
Northwest_Coastal
British_Columbia_not_Fraser
Northwest_Puget_Sound
Alaska_W
California_S
Alaska_SE
Alaska_S
Type_of_study
51 54 2 0 8 0 0 3
Lab_Experimental
Field_RemoteSensing
Review_MetaAnalysis
Theoretical_Opinion
Model
Projections_physical
Projections_ecosystem
Projections_salmon
Species
34 0 15 8 6 12 6 0 0 9 2 5 2 5 2 0 2
O_tshawatscha
General
S_salar
O_mykiss
O_nerka
Other_fish
O_kisutch
Salmonids_general
Other_species
S_trutta
O_keta
O_gorbuscha
O_clarkii
S_fontinalis
S_confluentus
S_malma
O_masou

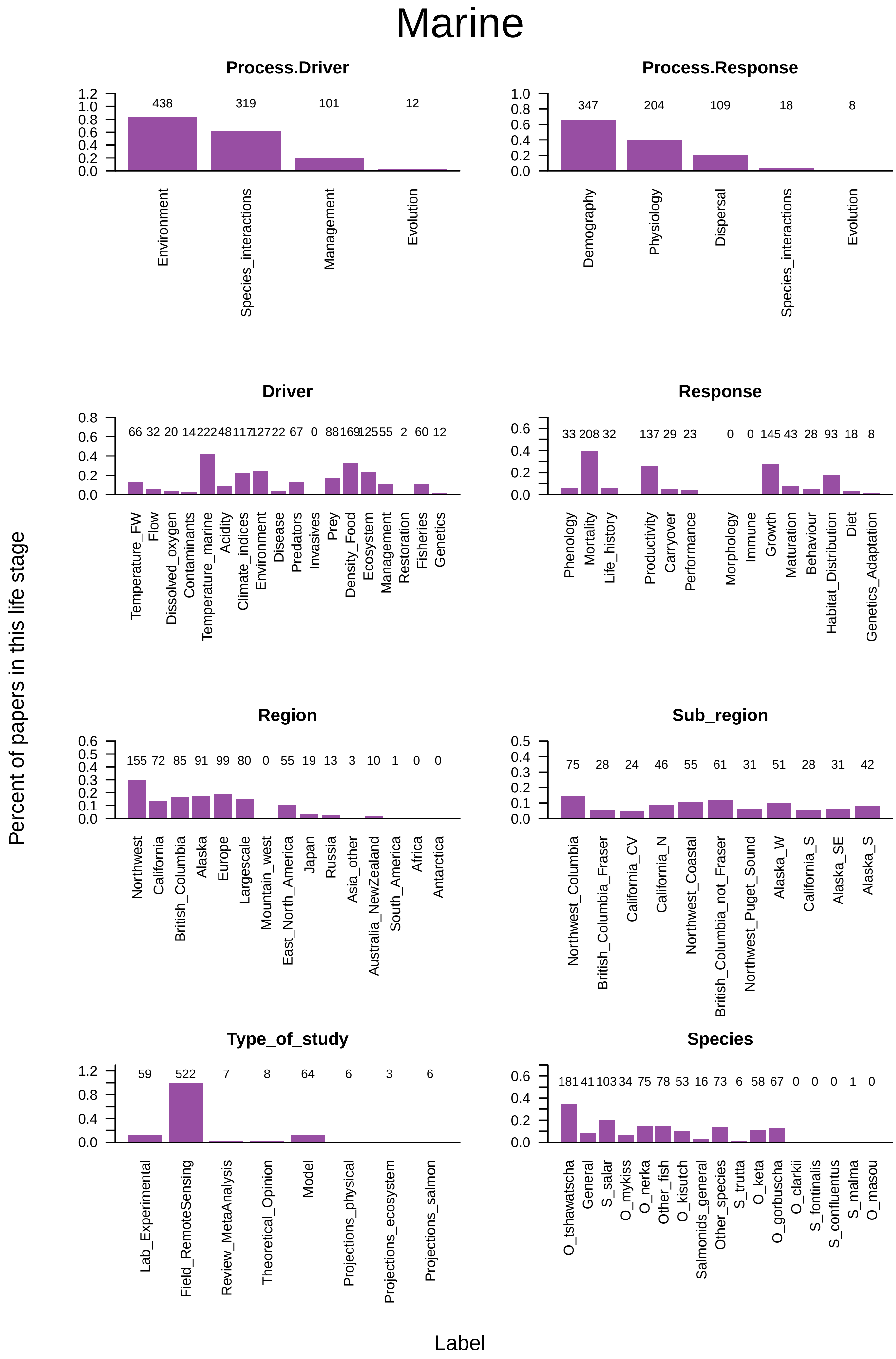
Juvenile



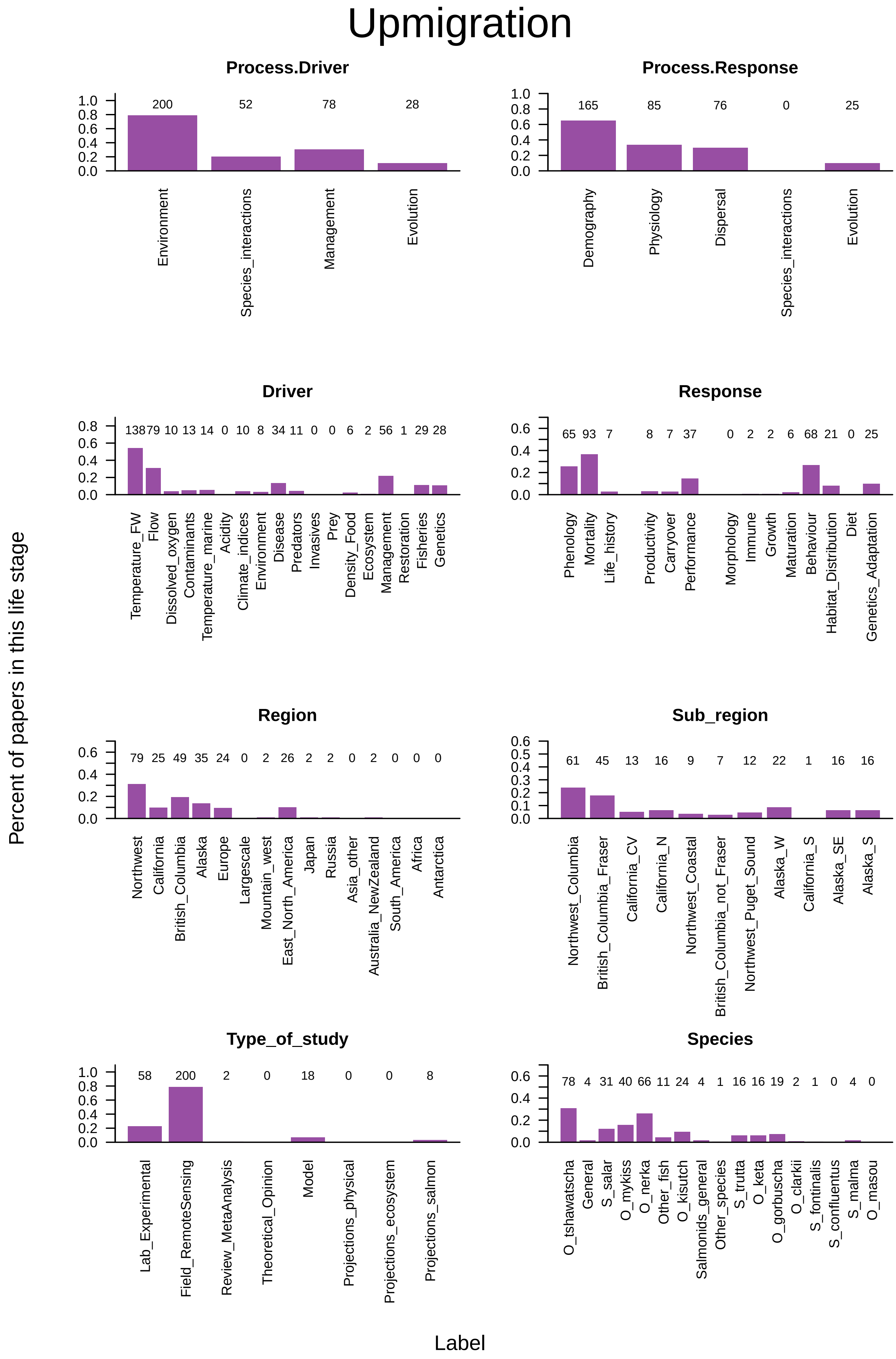
Process.Driver
525
223
122
33
Environment
Species_interactions
Management
Evolution
Process.Response
299
301
158
3
25
Demography
Physiology
Dispersal
Species_interactions
Evolution
Driver
Response
Region
Sub_region
Type_of_study
Species
Percent of papers in this life stage
Label



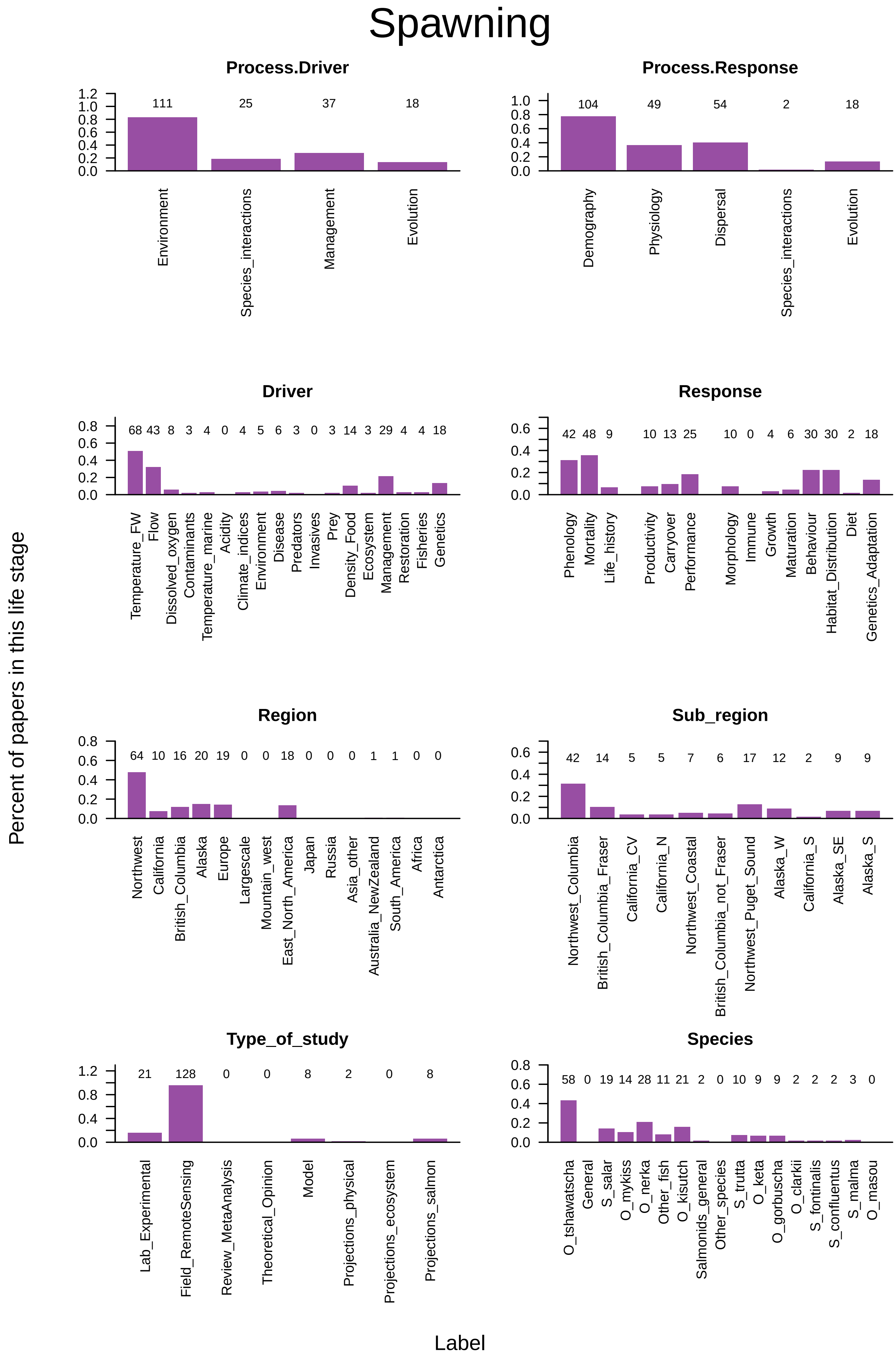
Outmigration
Process.Driver
178 66 57 5
Environment
Species_interactions
Management
Evolution
Process.Response
155 77 70 3 4
Demography
Physiology
Dispersal
Species_interactions
Evolution
Driver
75 65 11 9 26 2 9 30 4 21 3 19 32 6 52 5 0 5
Temperature_FW
Flow
Dissolved_oxygen
Contaminants
Temperature_marine
Acidity
Climate_indices
Environment
Disease
Predators
Invasives
Prey
Density_Food
Ecosystem
Management
Restoration
Fisheries
Genetics
Response
75 88 18 0 21 6 0 0 44 5 41 35 3 4
Phenology
Mortality
Life_history
Productivity
Carryover
Performance
Morphology
Immune
Growth
Maturation
Behaviour
Habitat_Distribution
Diet
Genetics_Adaptation
Region
57 46 24 10 48 2 0 13 5 0 3 0 0 0 0
Northwest
California
British_Columbia
Alaska
Europe
Largescale
Mountain_west
East_North_America
Japan
Russia
Asia_other
Australia_NewZealand
South_America
Africa
Antarctica
Sub_region
40 10 35 10 4 14 16 1 5 5 9
Northwest_Columbia
British_Columbia_Fraser
California_CV
California_N
Northwest_Coastal
British_Columbia_not_Fraser
Northwest_Puget_Sound
Alaska_W
California_S
Alaska_SE
Alaska_S
Type_of_study
31 175 2 0 17 0 0 1
Lab_Experimental
Field_RemoteSensing
Review_MetaAnalysis
Theoretical_Opinion
Model
Projections_physical
Projections_ecosystem
Projections_salmon
Species
78 1 55 40 20 8 19 2 1 9 13 7 2 0 2 3 1
O_tshawatscha
General
S_salar
O_mykiss
O_nerka
Other_fish
O_kisutch
Salmonids_general
Other_species
S_trutta
O_keta
O_gorbuscha
O_clarkii
S_fontinalis
S_confluentus
S_malma
O_masou
Percent of papers in this life stage
Label



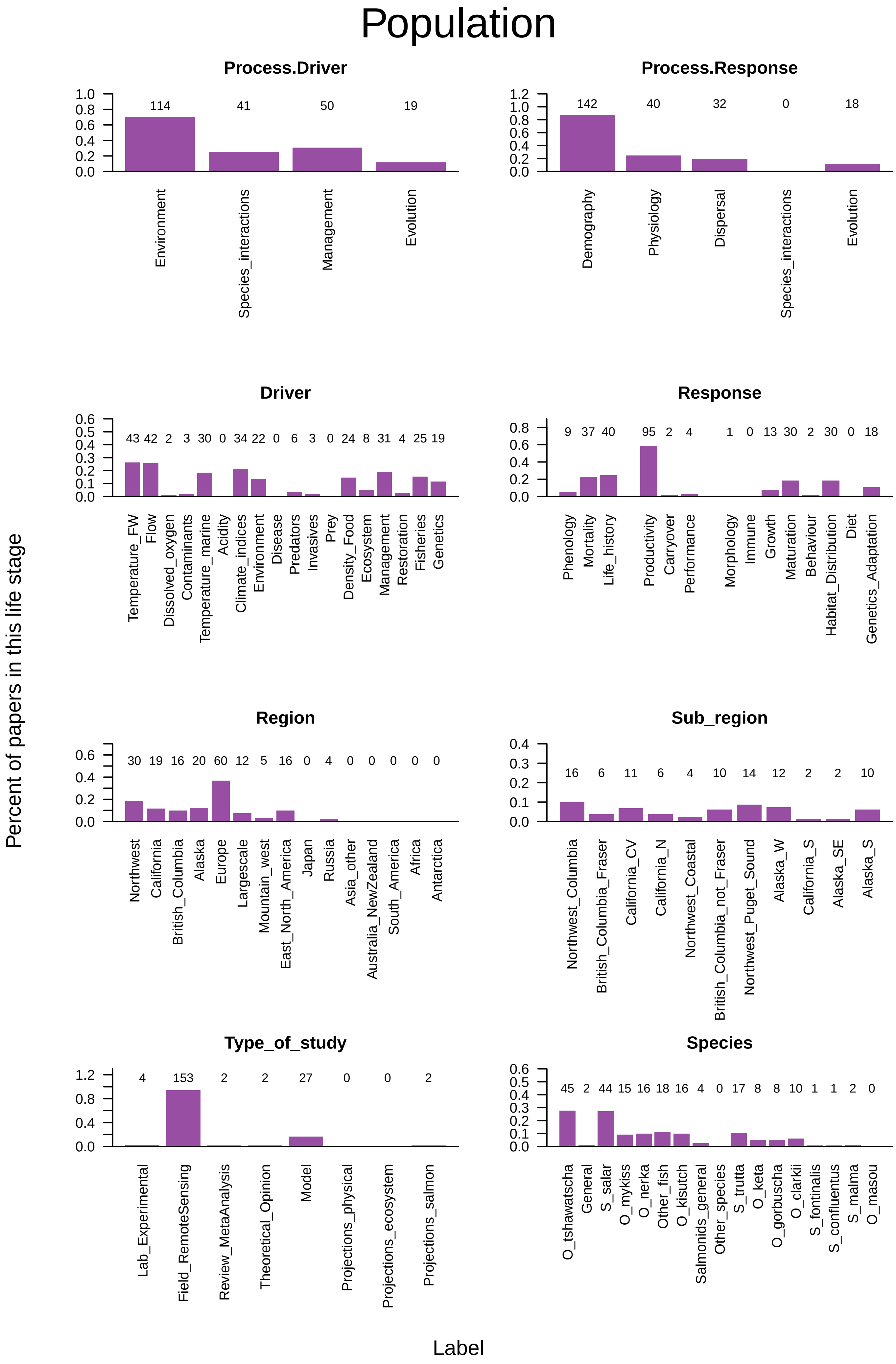
Marine
Process.Driver
438 319 101 12
Environment
Species_interactions
Management
Evolution
Process.Response
347 204 109 18 8
Demography
Physiology
Dispersal
Species_interactions
Evolution
Driver
66 32 20 14 222 48 117 127 22 67 0 88 169 125 55 2 60 12
Temperature_FW
Flow
Dissolved_oxygen
Contaminants
Temperature_marine
Acidity
Climate_indices
Environment
Disease
Predators
Invasives
Prey
Density_Food
Ecosystem
Management
Restoration
Fisheries
Genetics
Response
33 208 32 137 29 23 0 0 145 43 28 93 18 8
Phenology
Mortality
Life_history
Productivity
Carryover
Performance
Morphology
Immune
Growth
Maturation
Behaviour
Habitat_Distribution
Diet
Genetics_Adaptation
Region
155 72 85 91 99 80 0 55 19 13 3 10 1 0 0
Northwest
California
British_Columbia
Alaska
Europe
Largescale
Mountain_west
East_North_America
Japan
Russia
Asia_other
Australia_NewZealand
South_America
Africa
Antarctica
Sub_region
75 28 24 46 55 61 31 51 28 31 42
Northwest_Columbia
British_Columbia_Fraser
California_CV
California_N
Northwest_Coastal
British_Columbia_not_Fraser
Northwest_Puget_Sound
Alaska_W
California_S
Alaska_SE
Alaska_S
Type_of_study
59 522 7 8 64 6 3 6
Lab_Experimental
Field_RemoteSensing
Review_MetaAnalysis
Theoretical_Opinion
Model
Projections_physical
Projections_ecosystem
Projections_salmon
Species
181 41 103 34 75 78 53 16 73 6 58 67 0 0 0 1 0
O_tshawatscha
General
S_salar
O_mykiss
O_nerka
Other_fish
O_kisutch
Salmonids_general
Other_species
S_trutta
O_keta
O_gorbuscha
O_clarkii
S_fontinalis
S_confluentus
S_malma
O_masou
Percent of papers in this life stage
Label



Upmigration
Process.Driver
200 52 78 28
Environment
Species_interactions
Management
Evolution
Process.Response
165 85 76 0 25
Demography
Physiology
Dispersal
Species_interactions
Evolution
Driver
138 79 10 13 14 0 10 8 34 11 0 0 6 2 56 1 29 28
Temperature_FW
Flow
Dissolved_oxygen
Contaminants
Temperature_marine
Acidity
Climate_indices
Environment
Disease
Predators
Invasives
Prey
Density_Food
Ecosystem
Management
Restoration
Fisheries
Genetics
Response
65 93 7 8 7 37 0 2 2 6 68 21 0 25
Phenology
Mortality
Life_history
Productivity
Carryover
Performance
Morphology
Immune
Growth
Maturation
Behaviour
Habitat_Distribution
Diet
Genetics_Adaptation
Region
79 25 49 35 24 0 2 26 2 2 0 2 0 0 0
Northwest
California
British_Columbia
Alaska
Europe
Largescale
Mountain_west
East_North_America
Japan
Russia
Asia_other
Australia_NewZealand
South_America
Africa
Antarctica
Sub_region
61 45 13 16 9 7 12 22 1 16 16
Northwest_Columbia
British_Columbia_Fraser
California_CV
California_N
Northwest_Coastal
British_Columbia_not_Fraser
Northwest_Puget_Sound
Alaska_W
California_S
Alaska_SE
Alaska_S
Type_of_study
58 200 2 0 18 0 0 8
Lab_Experimental
Field_RemoteSensing
Review_MetaAnalysis
Theoretical_Opinion
Model
Projections_physical
Projections_ecosystem
Projections_salmon
Species
78 4 31 40 66 11 24 4 1 16 16 19 2 1 0 4 0
O_tshawatscha
General
S_salar
O_mykiss
O_nerka
Other_fish
O_kisutch
Salmonids_general
Other_species
S_trutta
O_keta
O_gorbuscha
O_clarkii
S_fontinalis
S_confluentus
S_malma
O_masou
Percent of papers in this life stage
Label



Spawning
Process.Driver
1.2 1.0 0.8 0.6 0.4 0.2 0.0
111 25 37 18
Environment
Species_interactions
Management
Evolution
Process.Response
1.0 0.8 0.6 0.4 0.2 0.0
104 49 54 2 18
Demography
Physiology
Dispersal
Species_interactions
Evolution
Driver
0.8 0.6 0.4 0.2 0.0
68 43 8 3 4 0 4 5 6 3 0 3 14 3 29 4 4 18
Temperature_FW
Flow
Dissolved_oxygen
Contaminants
Temperature_marine
Acidity
Climate_indices
Environment
Disease
Predators
Invasives
Prey
Density_Food
Ecosystem
Management
Restoration
Fisheries
Genetics
Response
0.6 0.4 0.2 0.0
42 48 9 10 13 25 10 0 4 6 30 30 2 18
Phenology
Mortality
Life_history
Productivity
Carryover
Performance
Morphology
Immune
Growth
Maturation
Behaviour
Habitat_Distribution
Diet
Genetics_Adaptation
Percent of papers in this life stage
Region
0.8 0.6 0.4 0.2 0.0
64 10 16 20 19 0 0 18 0 0 0 1 1 0 0
Northwest
California
British_Columbia
Alaska
Europe
Largescale
Mountain_west
East_North_America
Japan
Russia
Asia_other
Australia_NewZealand
South_America
Africa
Antarctica
Sub_region
0.6 0.4 0.2 0.0
42 14 5 5 7 6 17 12 2 9 9
Northwest_Columbia
British_Columbia_Fraser
California_CV
California_N
Northwest_Coastal
British_Columbia_not_Fraser
Northwest_Puget_Sound
Alaska_W
California_S
Alaska_SE
Alaska_S
Type_of_study
1.2 0.8 0.4 0.0
21 128 0 0 8 2 0 8
Lab_Experimental
Field_RemoteSensing
Review_MetaAnalysis
Theoretical_Opinion
Model
Projections_physical
Projections_ecosystem
Projections_salmon
Species
0.8 0.6 0.4 0.2 0.0
58 0 19 14 28 11 21 2 0 10 9 9 2 2 2 3 0
O_tshawatscha
General
S_salar
O_mykiss
O_nerka
Other_fish
O_kisutch
Salmonids_general
Other_species
S_trutta
O_keta
O_gorbuscha
O_clarkii
S_fontinalis
S_confluentus
S_malma
O_masou
Label



Population
Process.Driver
114 41 50 19
Environment
Species_interactions
Management
Evolution
Process.Response
142 40 32 0 18
Demography
Physiology
Dispersal
Species_interactions
Evolution
Driver
43 42 2 3 30 0 34 22 0 6 3 0 24 8 31 4 25 19
Temperature_FW
Flow
Dissolved_oxygen
Contaminants
Temperature_marine
Acidity
Climate_indices
Environment
Disease
Predators
Invasives
Prey
Density_Food
Ecosystem
Management
Restoration
Fisheries
Genetics
Response
9 37 40 95 2 4 1 0 13 30 2 30 0 18
Phenology
Mortality
Life_history
Productivity
Carryover
Performance
Morphology
Immune
Growth
Maturation
Behaviour
Habitat_Distribution
Diet
Genetics_Adaptation
Region
30 19 16 20 60 12 5 16 0 4 0 0 0 0 0
Northwest
California
British_Columbia
Alaska
Europe
Largescale
Mountain_west
East_North_America
Japan
Russia
Asia_other
Australia_NewZealand
South_America
Africa
Antarctica
Sub_region
16 6 11 6 4 10 14 12 2 2 10
Northwest_Columbia
British_Columbia_Fraser
California_CV
California_N
Northwest_Coastal
British_Columbia_not_Fraser
Northwest_Puget_Sound
Alaska_W
California_S
Alaska_SE
Alaska_S
Type_of_study
4 153 2 2 27 0 0 2
Lab_Experimental
Field_RemoteSensing
Review_MetaAnalysis
Theoretical_Opinion
Model
Projections_physical
Projections_ecosystem
Projections_salmon
Species
45 2 44 15 16 18 16 4 0 17 8 8 10 1 1 2 0
O_tshawatscha
General
S_salar
O_mykiss
O_nerka
Other_fish
O_kisutch
Salmonids_general
Other_species
S_trutta
O_keta
O_gorbuscha
O_clarkii
S_fontinalis
S_confluentus
S_malma
O_masou
Percent of papers in this life stage
Label