ARCTIC
VOL. 68, NO. 4 (DECEMBER 2015) P. S1–S5
http://dx.doi.org/10.14430/arctic4521

Conceptual Models for Marine and Freshwater Systems in Alaska: Flexible Tools for Research Planning, Prioritization and Communication

Suresh Andrew Sethi[1] and Tuula Hollmen[2]

APPENDIX 1
LINKAGE RATINGS EXERCISE FOR ZOOPLANKTON-HERRING-WHALE CONCEPTUAL ECOLOGICAL MODEL

Dear respondent,

Please rate six properties of linkages in the zooplankton-herring-whale conceptual ecological model, using the rating scales provided below. Please rate two-way linkages separately, i.e., for $X \leftrightarrows Y$, rate the properties of $X \rightarrow Y$ and $X \leftarrow Y$ separately.

A) Direction of interaction: positive or negative linkage:

+ _ The linkage $X \rightarrow Y$ indicates a positive effect of X on Y.
– _ The linkage $X \rightarrow Y$ indicates a negative effect of X on Y.

B) Strength of interaction:

1 _ The linkage between the entities is very weak, with the behavior of Y largely independent from the behavior of X, i.e., the state of X affects Y very little.
2 _
3 _ The linkage is moderate; changes in the state of X lead to moderately sized changes in the state of Y; however, X is not a main driver of change in Y.
4 _
5 _ The linkage is very strong, where a small change in the state of X leads to a large change in the state Y; X is a main driver of Y.

C) What spatial scale does the linkage operate at?

1 _ Highly localized, on the scale of a few hundred meters or less, e.g., on a single rocky outcrop.
2 _ Localized, on the scale of 1 to 10 km, e.g., in a single small bay.
3 _ Somewhat localized, on the scale of 11 to 100 km, e.g., in a commercial fishing district.
4 _ Regional, on the scale of 101 to 1000 km, e.g., in an ocean region such as Cook Inlet or Prince William Sound.
5 _ Basin-wide, 1001 to 10 000 km, e.g., in the Gulf of Alaska.

D) What temporal scale does the linkage operate at?

1 _ Daily
2 _ Monthly or seasonal (e.g., during spring)
3 _ Annual
4 _ Decades
5 _ Centuries or longer

[1] Corresponding author: Fisheries and Ecological Services, U.S. Fish and Wildlife Service, 1011 E. Tudor Road, M/S 331, Anchorage, Alaska 99503, USA; suresh_sethi@fws.gov
[2] Alaska SeaLife Center and University of Alaska Fairbanks, PO Box 1329, Seward, Alaska 99664, USA

E) Inherent variability of the linkage (over the temporal and spatial scales identified in questions C and D above).

1 _ The strength of influence and direction of influence in the linkage are highly variable: the entities behave largely independently.
2 _
3 _ The linkage is moderately variable: with everything else the same, sometimes the state of *X* influences the state of *Y* in a predictable fashion, and sometimes it does not.
4 _
5 _ The linkage is direct and persistent: *X* results in a predictable change in *Y*.

F) State of knowledge about the linkage:

1 _ The linkage, be it strong or weak, is pure speculation with no anecdotal, observational, or experimental evidence to support it.
2 _
3 _ Some experimental or observational evidence exists to support the linkage in the local system or directly comparable systems; however, the evidence is not conclusive.
4 _
5 _ The linkage, be it strong or weak, is well understood; knowledge of the mechanisms with which *X* affects *Y* is supported by both experimental and observational data. Empirical or theoretical models are available with which to predict the effect of *X* on *Y*.

APPENDIX 2
CHINOOK SALMON CONCEPTUAL MODEL: STRESSOR–LIFE HISTORY STAGE IMPACT RATINGS EXERCISE

Dear respondent,

Using the provided table of stressor–life stage combinations, please rate three properties of the stressors and their impacts on Chinook salmon life history stages. Judgment rating scales are provided below.

A) Strength of impact (consider stressor $X \rightarrow$ stage Y):

1 _ The impact of the stressor is very weak: the dynamics of the life history stage are largely independent of the dynamics of the stressor, i.e., the state of the stressor has very little effect on the life stage.
2 _
3 _ The impact is moderate: changes in the state of the stressor lead to moderately sized changes in the state of the life stage; however, the stressor is not a main driver of change in the life stage.
4 _
5 _ The impact is very strong: a small change in the state of the stressor leads to a large change in the state of the life stage. The stressor is a main driver of the life stage.

B) State of knowledge about the stressor and its impact:

1 _ The stressor impact, be it strong or weak, is pure speculation, with no anecdotal, observational, or experimental evidence to support it.
2 _
3 _ Some experimental or observational evidence exists to support the existence of the stressor impact in the local system or directly comparable systems; however, the evidence is not conclusive.
4 _
5 _ The stressor impact, be it strong or weak, is well understood: knowledge of the mechanisms with which the stressor affects the life stage is supported by both experimental and observational data. Empirical or theoretical models are available with which to predict the effect of the stressor on the life stage.

C) Management and research attention given to a stressor:

1 _ No resources are being devoted locally or in comparable systems to studying or managing the stressor and its impact.
2 _
3 _ Some resources are devoted locally or in comparable systems elsewhere to studying or managing the stressor and its impact; study and management of this stressor in the local system are best characterized as opportunistic.
4 _
5 _ The stressor and its impact are a major focus of state, federal, academic, and nongovernmental organizations' management and research activities. Resources are devoted to understanding and managing this stressor in the local system and in comparable systems elsewhere.

APPENDIX 3
CHINOOK SALMON STRESSOR – LIFE HISTORY STAGE IMPACT CONSENSUS RATINGS[1]

Life stage	Stressor	Impact rating	Knowledge rating	Attention rating	SD impact rating	SD knowledge rating	SD attention rating	Prioritization score[2]
Egg Incubation	Siltation	4.3	3.7	2.3	1.1	1.2	1.5	2.7
	Flow-related displacement	3.8	3.4	2.2	1.1	1.4	1.5	2.7
	Impaired water quality	3.5	3.2	1.8	0.7	0.9	1.1	**2.8**
	Water temperature (warm)	3.0	3.7	2.1	0.8	1.2	1.1	2.4
	Water temperature (cold)	2.6	3.5	1.8	1.1	1.1	1.0	2.4
	Escapement quality and fishery selection	2.6	2.2	1.9	1.8	0.6	1.4	**2.8**
	Predation	2.4	2.6	1.7	1.0	1.0	1.1	2.7
	Hatchery-related genetic introgression	2.4	2.4	1.4	1.2	1.1	0.5	**2.8**
	Escapement quantity (harvest)	2.1	2.0	1.7	1.7	0.9	1.5	**2.8**
	Disease	1.8	2.2	1.3	0.9	1.0	0.5	2.7
	Space-limited displacement (competition)	1.3	2.1	1.4	0.5	1.0	0.8	2.6
	Mean	2.7	2.8	1.8	1.1	1.0	1.1	2.7
Emergence-alevin	**Flow-related displacement**	3.3	2.7	1.8	1.1	0.9	1.0	**2.9**
	Siltation	3.1	2.8	1.7	1.4	1.1	1.1	2.8
	Water temperature (warm)	2.7	3.0	1.6	0.8	0.9	1.0	2.7
	Impaired water quality	2.7	2.7	1.6	1.3	1.3	1.0	2.8
	Predation	2.6	2.7	1.5	1.3	1.1	0.8	2.8
	Water temperature (cold)	2.5	2.8	1.6	1.0	1.1	1.0	2.7
	Escapement quality and fishery selection	2.0	1.7	1.7	1.6	0.8	1.5	2.8
	Hatchery-related genetic introgression	1.8	1.7	1.2	0.8	0.7	0.4	**2.9**
	Disease	1.7	1.8	1.2	0.8	0.8	0.4	**2.9**
	Mean	2.5	2.4	1.5	1.1	1.0	0.9	2.8
Freshwater rearing: summer	Food availability	4.4	3.3	2.5	0.8	1.3	1.2	2.8
	Predation	4.3	3.4	2.0	0.8	1.1	1.1	**2.9**
	Impaired habitat connectivity	3.8	3.0	2.6	1.0	1.1	1.6	2.7
	Water temperature (warm)	3.7	2.9	1.9	0.8	1.1	1.3	**2.9**
	Flow-related displacement	3.2	2.5	1.7	1.5	1.1	0.7	**3.0**
	Impaired water quality	3.0	2.8	2.1	1.2	0.9	1.1	2.7
	Water temperature (cold)	2.8	2.8	1.8	1.5	1.1	1.1	2.7
	Space-limited displacement (competition)	2.8	2.5	1.7	1.0	1.0	1.1	2.8
	Disease	2.4	2.3	1.6	1.1	0.7	0.7	2.8
	Siltation	1.9	1.8	1.5	1.1	0.8	0.8	2.8
	Escapement quality and fishery selection	1.8	1.6	1.4	1.3	0.8	1.0	**2.9**
	Hatchery-related genetic introgression	1.5	1.8	1.3	0.7	0.8	0.7	2.8
	Mean	3.0	2.6	1.8	1.1	1.0	1.0	2.8
Freshwater rearing: winter	**Predation**	4.0	2.1	1.9	0.8	0.7	0.9	**3.3**
	Space-limited displacement (competition)	3.6	2.1	1.8	1.4	0.9	1.1	**3.2**
	Water temperature (cold)	3.5	2.9	1.7	1.4	1.2	0.9	2.9
	Impaired habitat connectivity	3.3	2.1	1.7	1.3	0.7	0.9	3.1
	Food availability	3.3	1.8	1.8	1.6	0.8	0.9	**3.2**
	Flow-related displacement	3.0	2.4	1.6	1.4	1.2	0.8	3.0
	Impaired water quality	2.4	1.7	1.3	1.4	0.7	0.7	3.1
	Water temperature (warm)	2.1	2.3	1.3	1.5	1.3	0.7	2.8
	Escapement quantity (harvest)	1.9	1.4	1.2	1.4	0.7	0.6	3.1
	Escapement quality and fishery selection	1.9	1.3	1.2	1.4	0.5	0.6	3.1
	Siltation	1.8	1.5	1.2	1.1	0.5	0.4	3.0
	Disease	1.6	1.7	1.2	0.8	0.8	0.4	2.9
	Hatchery-related genetic introgression	1.6	1.4	1.0	1.0	0.5	0.0	3.0
	Mean	2.6	1.9	1.5	1.3	0.8	0.7	3.1
Smolting migration/ ocean arrival	Predation	4.1	3.0	2.1	0.9	0.8	1.1	3.0
	Food availability	3.9	2.4	1.7	1.4	0.7	0.9	**3.2**
	Impaired habitat connectivity	3.2	2.8	2.3	1.3	0.8	1.3	2.7
	Water temperature (cold)	2.8	1.9	1.5	1.4	0.7	0.8	**3.1**
	Water temperature (warm)	2.8	2.1	1.4	1.2	0.7	0.7	**3.1**
	Flow-related displacement	2.4	1.9	1.6	1.1	0.9	0.8	2.9
	Impaired water quality	2.4	2.0	1.6	1.3	0.8	0.8	2.9
	Space-limited displacement (competition)	1.9	1.4	1.1	1.1	0.5	0.3	**3.1**
	Disease	1.6	1.5	1.1	0.8	0.5	0.3	3.0
	Hatchery-related genetic introgression	1.6	1.7	1.4	1.1	1.1	0.7	2.8
	Siltation	1.4	1.5	1.2	0.7	0.7	0.6	2.9
	Mean	2.6	2.0	1.5	1.1	0.8	0.8	3.0

APPENDIX 3
CHINOOK SALMON STRESSOR – LIFE HISTORY STAGE IMPACT CONSENSUS RATINGS[1] – *continued*

Life stage	Stressor	Impact rating	Knowledge rating	Attention rating	SD impact rating	SD knowledge rating	SD attention rating	Prioritization score[2]
Ocean rearing	**Food availability**	4.8	2.9	2.5	0.4	1.4	1.2	**3.1**
	Predation	3.7	2.6	2.2	0.9	1.1	1.2	**2.9**
	Water temperature (cold)	3.5	2.5	2.6	1.3	1.2	1.3	2.8
	Water temperature (warm)	3.1	2.3	2.1	1.4	0.8	1.3	2.9
	Disease	2.6	2.2	2.1	1.0	1.0	1.1	2.7
	Escapement quality and fishery selection	2.6	1.9	2.0	1.4	0.9	1.5	2.9
	Escapement quantity (harvest)	2.4	2.1	2.4	1.6	1.3	1.9	2.6
	Impaired water quality	2.1	1.6	1.7	1.6	0.8	1.3	2.9
	Hatchery-related genetic introgression	2.0	1.4	1.3	1.2	0.5	0.7	**3.1**
	Mean	3.0	2.2	2.1	1.2	1.0	1.3	2.9
Spawning: migration	Escapement quantity (harvest)	4.7	4.0	4.4	0.5	1.1	0.8	2.1
	Escapement quality and fishery selection	4.4	3.6	3.7	0.8	1.0	0.9	2.3
	Impaired habitat connectivity	3.3	3.2	3.0	1.2	0.8	1.4	2.3
	Water temperature (warm)	3.1	2.8	2.2	1.5	1.1	0.8	2.7
	Disease	2.9	2.6	2.8	1.5	0.7	0.8	2.5
	Predation	2.8	3.1	2.1	1.1	1.0	1.4	2.5
	Hatchery-related genetic introgression	2.6	2.2	1.5	1.3	0.8	0.5	**2.9**
	Water temperature (cold)	2.5	2.5	1.8	1.6	1.3	0.8	2.7
	Spawning habitat availability	2.3	2.4	1.9	1.8	1.4	1.3	2.6
	Impaired water quality	2.2	1.9	1.9	1.1	0.9	0.9	**2.8**
	Flow-related displacement	1.7	1.4	1.5	1.3	0.7	1.0	**2.9**
	Space-limited displacement (competition)	1.5	2.0	1.3	0.8	1.3	0.7	2.7
	Mean	2.8	2.6	2.3	1.2	1.0	0.9	2.6
Spawning: egg deposition	**Spawning habitat availability**	4.8	2.8	2.4	0.6	0.6	1.1	**3.2**
	Escapement quality and fishery selection	3.9	2.7	3.0	1.4	1.4	1.4	2.7
	Escapement quantity (harvest)	3.7	2.9	3.4	1.7	1.4	1.6	**2.4**
	Predation	3.6	2.7	1.9	1.3	0.5	0.9	3.0
	Siltation	3.1	2.6	1.8	1.4	1.2	1.0	2.9
	Impaired water quality	3.0	2.5	1.6	1.2	1.1	1.1	2.9
	Water temperature (warm)	2.9	2.7	1.9	1.7	1.3	1.0	2.7
	Flow-related displacement	2.8	2.4	1.6	1.5	1.1	0.8	2.9
	Water temperature (cold)	2.6	2.6	1.7	1.7	1.3	1.1	2.7
	Hatchery-related genetic introgression	2.5	1.7	1.6	1.2	0.7	0.8	**3.0**
	Space-limited displacement (competition)	2.3	1.9	1.4	1.3	1.0	0.7	**3.0**
	Disease	2.2	2.1	1.8	1.7	1.3	1.0	2.7
	Impaired habitat connectivity	1.9	1.7	1.2	1.3	0.9	0.4	**3.0**
	Mean	3.0	2.4	1.9	1.4	1.1	1.0	2.9

[1] Results are from 10 respondents. Stressors within each life stage are ranked by impact rating (See Appendix 2 for rating questions). SD = standard deviation of responses. Bold type indicates the top three stressors (by prioritization score) in each life stage. (In some instances, equal prioritization scores led to highlighting additional stressors.)

[2] Prioritization score = 0.33 × (impact rating) + 0.33 × (absolute value (knowledge rating − 5.0)) + 0.33 × (absolute value (attention rating − 5.0)). The knowledge and attention ratings were translated in such a way that a high score indicates a low state of knowledge or little research or management attention devoted to a stressor and its impact. High scores therefore indicate high-priority items for future management and research efforts.