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Identification of Physical Habitats Limiting the Production of Coho Salmon in Western Oregon and Washington

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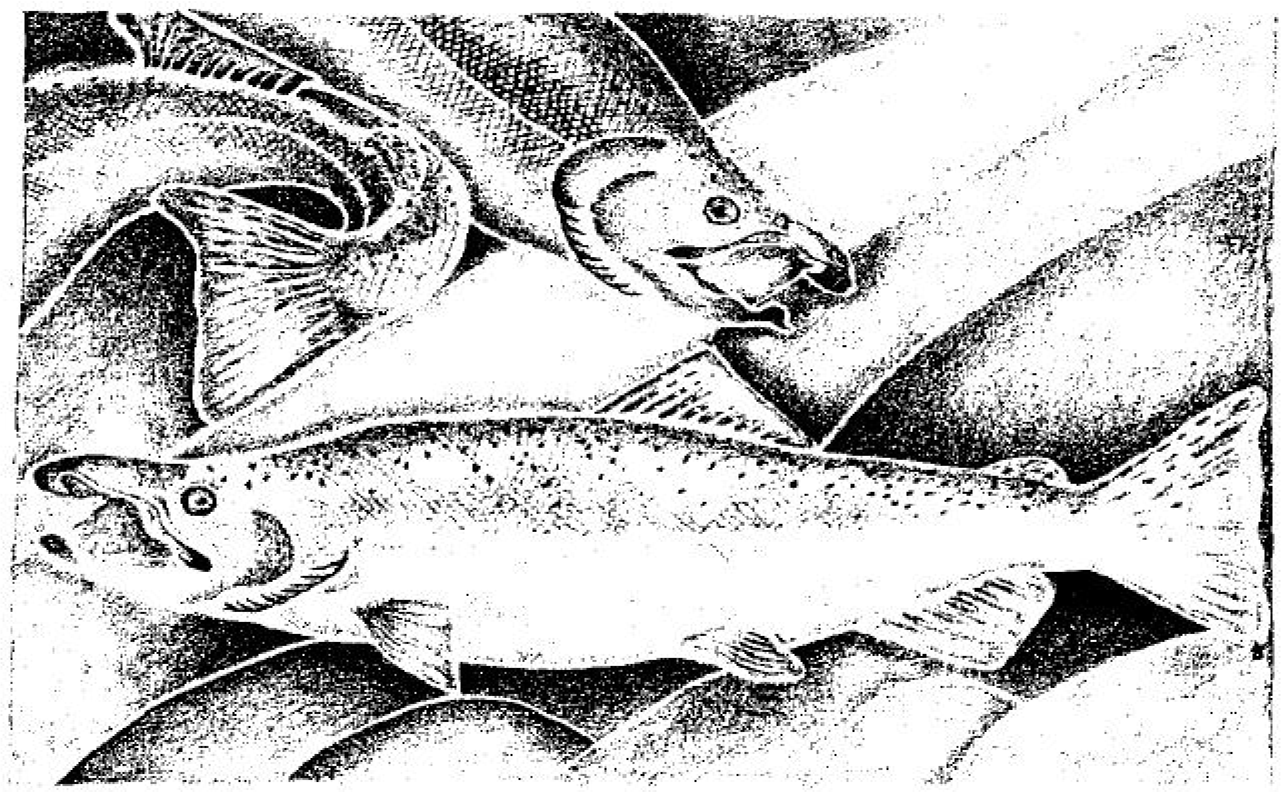

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Abstract

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Fishery managers are currently spending millions of dollars per year on habitat enhancement for anadromous salmonids but often do not have the tools needed to ensure success. An analysis of factors limiting production of salmonids in streams must be completed before any habitat-enhancement program is begun. This paper outlines the first formal procedure for identifying physical habitats limiting production of coho salmon.

Keywords: Coho salmon, limiting factors, dichotomous key.

Contents

Introduction

The following key is designed to help fishery managers identify factors limiting the production of juvenile coho salmon *(Oncorhynchus kisutch* (Walbaum)) in streams of coastal and interior (west of the Cascade Range) Oregon and Washington. The key is most accurate for streams up to large fourth-order and small fifth-order streams (Strahler 1957) in size. It is designed to identify potential physical limitations to fish production that may be moderated or removed by habitat rehabilitation or enhancement programs.

Information Needs

The key directs managers to possible factors limiting production of coho salmon in streams, but the answer must be carefully scrutinized. The key is only as good as the inventory information entered into it. If the inventory data are incomplete or inaccurate, the key will undoubtedly produce wrong answers. It is also impossible to develop a key that will be correct in all cases when work is done in such a broad geographic area having many geologic types. Managers familiar with specific streams therefore will have to evaluate the suggestions of the key, determine their validity, and make final decisions about the best course of action.

Correct use of this key requires at least two surveys of the habitat in the entire portion of a basin used by coho salmon. The surveys should be done by following the methods of Hankin and Reeves (1988). One survey should be done during the low-flow period in late summer or early fall. The other should be made in the late winter or early spring during nonflood flows (that is, a flow when a spawning survey would normally be done). Quantitative estimates should be made of summer rearing area during the summer survey and of winter rearing area, spawning gravel, and early rearing habitat during the winter survey. Calculations of the amount of habitat can easily be done on any spreadsheet the data is entered on.

Besides the above data, information on summer and winter water temperatures and stream gradient are necessary to use the key. Knowledge about smolt output and adult escapement in a system where a limiting-factors analysis is being conducted will improve the performance of the key but is not necessary to use it.

Estimates of the total number of coho salmon present during the low-flow survey and the pattern of habitat use are not required to use this key but use of this information will greatly improve the performance of the key. We strongly encourage the collection of fish population data whenever possible. Population estimates can be made either by electrofishing and seining or by a combination of electrofishing, seining, and direct observation. The combination of techniques is probably the most efficient. The procedures for making these estimates are described by Hankin and Reeves (1988). Even when fish population data are available, we suggest that the key be used with and without them to see if there is an agreement on the limiting factor.

Biological Basis for the Key

The key is based on a model that approaches the problem of identifying factors by making a simultaneous comparison of the habitat requirements of different life history stages (or the same stage in different seasons) of a species (Nickelson 1986). The model assumes that when the habitat needed by a species during a particular season of the year is in short supply, a bottleneck is created and the species will suffer extensive density-dependent mortality. If the population is reduced to a level such that subsequent habitats are underseeded, the habitat producing the bottleneck is identified as the limiting habitat. We recognize that factors other than physical features, such as nutrients and food availability, may limit production of juvenile salmonids. We feel, however, that neither the procedures for identifying such limitations nor the techniques for eliminating them are well developed and therefore they are not yet useful to fishery managers.

The habitat surveys will generate two estimates of the amount of habitat used by coho salmon in a basin. The first estimates the total amount of habitat present in the basin at a given time. It is calculated by following Hankin and Reeves (1988). The second estimate, referred to as the "usable habitat," represents the amount of habitat actually usable by juvenile coho salmon and is estimated by standardizing all habitats against the best habitat. The latter is what is used in the key to estimate the potential fish populations because all types of habitats do not have the same capability to rear juvenile coho salmon. The coefficients used to estimate the present usable habitat are calculated by dividing the average density of fish found in a particular habitat type by the average density of fish found in the most productive habitat type. This has been done in the key for early rearing habitat and winter habitat. The coefficients for the various early rearing and winter habitats are in appendix 1. Data used to develop the coefficients for each habitat type are from Solazzi and others (1987) and Everest and others (1987). Present usable habitat is always less than the total amount of habitat.

The habitat and smolt factors contained in this key were designed to aid in identification of limiting factors. Habitat factors represent a combination of survival rate between life history stages and the amount of habitat needed per individual at each life history stage. They help determine the amount of habitat necessary at a given life history stage to support or produce the potential summer population.

The smolt factor is the potential number of smolts that could be produced from a given life history stage if no limiting factors occurred at a life history stage further along in the life cycle. This factor is the mean density of fish expected at a given life history stage multiplied by the density-independent mortality rate of the succeeding life history stages. The smolt factor aids in determining which habitat is the most limiting. The data and equations used to calculate these factors are shown in appendix 2.

Definitions of the Freshwater Habitat Requirements of Coho Salmon

The following definitions of habitat required by coho salmon at each freshwater life history stage will be used. Habitat units will be classified as pools, riffles, glides, and side channels according to Bisson and others (1982).

Spawning: Gravel 1-20 cm in size (about the size of peas to oranges) that is <30 percent fines (<3 mm) and stable. The minimum size of an individual patch of gravel that should be included in this estimate is 2 m^2. This gravel should be located within the winter low-flow boundary of the channel.

Early rearing habitat: Shallow (<30 cm), quiet areas (<10 cm/s) usually associated with backwater pools, dam pools, and beaver ponds but also found in side channels and along the margins of other types of habitats.

Summer rearing habitat: Pools of all types and beaver ponds are the preferred habitats. Glides and boulder-cobble riffles are also included but are much less preferred habitats.

Winter rearing habitat:
Areas with mean winter water temperatures ≥7 °C— Deep (>80 cm), quiet (<10 cm/s) areas usually associated with an abundance of cover. Beaver ponds, backwater pools, deep lateral scour pools, dam pools, and side-channels are preferred habitats. Less preferred habitats include lateral scour pools and plunge pools.

Areas with mean winter water temperatures <7 °C—Beaver ponds and off-channel areas associated with an abundance of cover, primarily large woody debris; also stream margins with concentrations of large woody debris and boulders that form pockets of deep (>0.5 m at winter base flow), slow (<0.3 m/s) water.

Key to Physical Limiting Factors

1. Stream gradient.
   a. Where average gradient in the basin is >3 percent, habitat is usually not preferred by coho salmon. Consider emphasis of other salmonid species (for example, steelhead trout) in habitats with >3 percent gradient. If coho salmon are already present in the system, check opportunities for development of off-channel rearing ponds or for improvement of habitat in short reaches with gradients of ≤3 percent.

   b. Where average gradient in the basin is ≤3 percent 2

2. Summer water temperatures.
   a. Minimum summer water temperature exceeds 20 °C for 2 weeks or more during summer low flow. Water temperature might limit production of presmolts by creating less favorable environmental conditions or by conferring advantage to nongame competitors. Possible solution: Correcting the temperature problems is the highest priority. Increase riparian revegetation and use of best watershed management practices in the basin. When suitable water temperatures are achieved, reanalyze for the limiting factors in the basin.

   b. Minimum summer water temperatures do not exceed 20 °C for more than 2 weeks 3

3. Summer population of juvenile coho salmon.
   a. Estimates available 4

   b. Estimates unavailable 24

4. Habitat configuration.
   a. ≥50 percent of wetted surface area in the basin used by juvenile coho salmon in summer is in pools 5

   b. <50 percent of wetted surface area in the basin used by juvenile coho salmon in summer is in pools 13

5. Coho salmon smolt output (from available data).
   a. Normal:' 40 smolts/100 m^2 in streams with <2500 m^2 total summer surface area/km.
   >35 smolts/100 m^2 in streams with 2500-5000 m^2 total summer surface area/km.

   >30 smolts/100 m^2 in streams with 5000 m^2 total summer surface area/km.

Rearing-habitat configuration is near optimum, and smolt production is normal for stream size. No improvements are needed to maintain smolt production from the area of the basin accessible to coho salmon. If some habitat in the basin is inaccessible, you may want to consider the productive potential of that habitat 23

   b. Smolt production below normal (less than in item a above) 6

   c. Smolt production unknown 6

6. Escapement of adults and seeding of habitats.
   Use the following formula to estimate the optimum number of spawning females:
   Optimum no. females/km =

$$\frac{\text{total rearing area}}{\text{(number km)(area/smolt)(egg-smolt survival)(fecundity)}}$$

Area/smolt = 2.5 m^2 in streams with <2500 m^2 total summer surface area/km.
= 3.0 m^2 in streams with 2500-5000 m^2 total summer surface area/km.
= 3.5 m^2 in streams with >5000 m^2 total summer surface area/km.

Egg to smolt survival = 0.02
Fecundity = 2500 eggs/female.

a. Escapement is optimum and it is assumed that the stream is producing fish at or near its production potential. Habitat manipulation is not needed to maintain coho salmon production. If some habitat in the basin is inaccessible, you may want to consider the productive potential of that habitat 23

b. Escapement less than optimum 7

c. Escapement unknown 8

' Based on: Marshall, D.E; Britton, E.W. 1980. Carrying capacity of coho streams. Unpublished file report. On file with: Fisheries and Oceans, Enhancement Services Branch, 1070 West Render Street, Vancouver, BC.

7. Escapement and seeding are below optimum.
   a. If optimum escapement will be established within 5 years 8

   b. If optimum escapement is not expected within 5 years because of overharvest or downstream mortality (for example, dams), it is difficult to justify habitat improvement measures.

8. Wild coho salmon population supplemented with hatchery fish.
   a. Yes 9

   b. No 10

9. Summer standing crop.
   Actual (estimated coho salmon population in basin) =______.
   Potential (estimated carrying capacity of habitat for hatchery fish in basin):

Area pools	x 0.6 fish/m^2	= ______ .
Area glides	x 0.3 fish/m^2	= ______.
Area cobble-boulder riffles	x 0.2 fish/m^2	= ______ .
Area beaver ponds	x 0.5 fish/m^2	= ______.
Area of pools in side channels	x 0.6 fish/m^2	= ______.
Potential summer population		= ______.

   a. Actual population is ≥80 percent of the potential population. Stocking program is seeding the available summer habitat. Managers should consider the possibility that winter habitat limits production of coho salmon 11

   b. Actual population is <80 percent of the potential population. Managers should reevaluate their hatchery stocking program before proceeding with habitat improvement.

10. Summer standing crop.
   Actual (estimated coho salmon population in basin) =____ .
   Potential (estimated carrying capacity of habitat in the basin):

Area pools	x 1.7 fish/m^2	= ______ .
Area glides	x 0.9 fish/m^2	= ______ .
Area cobble-boulder riffles	x 0.4 fish/m^2	= ______ .
Area beaver ponds	x 1.3 fish/m^2	= ______ .
Area side-channels	x 1.7 fish/m^2	= ______ .
Potential summer population		= ______ .

   a. Actual population is ≥80 percent of the potential population. Manipulation of spawning, early rearing, or summer habitat could increase production by a maximum of only 20 percent. Managers should consider the possibility that winter habitat limits production of coho salmon 11

   b. Actual population <80 percent of the potential population 12

11. Summer habitat is near carrying capacity, winter habitat could limit full production potential of the basin. Enter basin data below to check adequacy of winter habitat.

a. If mean winter temperature is ≥7 °C:

Habitat	Potential summer population	Area/ survival factor	Area needed (m^2)	Usable area (m^2)	Smolt factor	Smolts produced
Summer rearing	________ X	0.6 =	___________	______	x 0.9 =	________
Winter rearing	________ X	0.4 =	___________	______	x 1.2 =	________

If the usable area is less than habitat area needed, increase the usable area to meet needs. Use the column showing smolts produced to identify the most limiting habitat (that is, the habitat producing the fewest smolts). When habitats are in balance, accessible portion of system is at full production potential. If some habitat in the basin is inaccessible, you may want to consider the productive potential of that habitat 23

If mean winter temperature is <7 °C:

Habitat	Potential summer population	Area/ survival factor	Area needed (m^2)	Usable area (m^2)	Smolt factor	Smolts produced
Summer rearing	_______X	0.6 =	_____	_____	x 0.4 =	_______
Winter rearing	_______X	0.2 =	_____	_____	x 1.6 =	_______

If the usable area is less than habitat area needed, increase the usable area to meet needs. Use the column showing smolts produced to identify the most limiting habitat (that is, the habitat producing the fewest smolts). When habitats are in balance, accessible portion of system is at full production potential. If some habitat in the basin is inaccessible, you may want to consider the productive potential of that habitat 23

12.. Summer habitat is >20 percent below carrying capacity. Spawning habitat, spring habitat, summer habitat, and winter habitat could limit the full production potential of the basin. Enter basin inventory data below to assess limiting factor(s).

a. If mean winter water temperature is ≥7 °C:

Habitat	Potential summer population	Area/ survival factor	Area needed (m^2)	Usable area (m^2)	Smolt factor	Smolts produced
Spawning	__________	0.006	_______	________	95.5	=________
Spring rearing	__________	0.3	_______	________	1.7	=________
Summer rearing	__________	0.6	_______	________	0.9	=________
Winter rearing	__________	0.4	_______	________	1.2	=________

If the usable area is less than habitat area needed, increase the usable area to meet needs. One or more habitat features might need to be increased. Use the column showing smolts produced to identify the most limiting habitat (that is, the habitat producing the fewest smolts). When habitats are in balance, accessible portion of system is at full production potential. If some habitat in the basin is inaccessible, you may want to consider the productive potential of that habitat 23

b. If mean winter water temperature is <7 °C.:

Habitat	Potential summer population		Area/ survival factor		Area needed (m^2)		Usable area (m^2)	Smolt factor		Smolts produced
Spawning	________	x	0.006	=	________	x	______	95.5	=	________
Spring rearing	________	x	0.3	=	________	x	______	1.7	=	________
Summer rearing	________	x	0.6	=	________	x	______	0.9	=	________
Winter rearing	________	x	0.4	=	________	x	______	1.2	=	________

If the usable area is less than habitat area needed, increase the usable area to meet needs. One or more habitat features might need to be increased. Use the column showing smolts produced to identify the most limiting habitat (that is, the habitat producing the fewest smolts). When habitats are in balance, accessible portion of system is at full production potential. If some habitat in the basin is inaccessible, you may want to consider the productive potential of that habitat 23

13. Habitat configuration is suboptimum, lacking pools. Smolt production from the basin is:
a. Normal (see footnote 1): >40 smolts/100 m^2 in streams with <2500 m^2 total summer surface area/km.
>35 smolts/100 m^2 in streams with 2500-5000 m^2 total summer surface are/km.

>30 smolts/100 m^2 in streams with >5000 m^2 total summer surface area/km.

Rearing habitat configuration is suboptimum, but smolt production is about normal for stream size. No improvements are needed to maintain smolt production from the area of the basin accessible to coho salmon. If some habitat in the basin is inaccessible, you may want to consider the productive potential of that habitat 23

b. Below normal (less than above) 14

c. Unknown 14

14. Escapement of adults and seeding of habitats.
Use the following formula to estimate the optimum number of spawning females:

Optimum no. females/km =

$$\frac{\text{total rearing area}}{(\text{number km})(\text{area/smolt})(\text{egg-smolt survival})(\text{fecundity})}$$

Area/smolt = 2.5 m^2 in streams with <2500 m^2 of total summer surface area/km.
= 3.0 m^2 in streams with 2500-5000 m^2 of total summer surface area/km.
= 3.5 m^2 in streams with >5000 m^2 of total summer surface area/km.

Egg to smolt survival = 0.02
Fecundity = 2500 eggs/female.

a. Escapement is optimum and it is assumed that the stream is producing fish at or near its production potential. Habitat manipulation is not needed to maintain coho salmon production. If some habitat in the basin is inaccessible, consider the productive potential of that habitat 23

b. Escapement less than optimum 15

c. Escapement unknown 16

15. Escapement and seeding are below optimum.
a. If optimum escapement will be established within 5 years 16

b. If optimum escapement is not expected within 5 years because of over-harvest or downstream mortality (for example, dams), it is difficult to justify habitat improvement measures.

16. Wild coho salmon population is supplemented with hatchery fish.
a. Yes 17

b. No 18

17. Summer standing crop.
Actual (estimated coho salmon population in basin) =______.
Potential (estimated carrying capacity of habitat for hatchery fish in basin):

Area pools	x 0.6 fish/m^2	=	___________
Area glides	x 0.3 fish/m2	=	___________
Area cobble-boulder riffles	x 0.2 fish/m^2	=	___________
Area beaver ponds	x 0.5 fish/m^2	=	___________
Area of pools in side channels	x 0.6 fish/m^2	=	___________
Potential summer population		=	_________

a. Actual population ≥80 percent of the potential population. The stocking program is seeding the available summer habitat. Managers should consider the possibility that winter habitat limits production of coho salmon 19
b. Actual population <80 percent of the potential population. Managers should reevaluate their hatchery stocking program before proceeding with habitat improvement.

18. Summer standing crop.
Actual (estimated coho salmon population in basin) =____.
Potential (estimated carrying capacity of habitat in the basin).

Area pools	x 1.7fish/m^2	=____.
Area glides	x 0.9fish/m^2	=____.
Area cobble-boulder riffles	x 0.4fish/m^2	=____.
Area beaver ponds	x 1.3 fish/m^2	= ____.
Area side-channels	x 1.7 fish/m^2	=
Potential summer population		= ____.

a. Actual population ≥80 percent of the potential population. The stocking program is seeding the available summer habitat. Managers should consider the possibility that winter habitat limits production of coho salmon 19

b. Actual population <80 percent of the potential population 20

19. Summer habitat is near carrying capacity, winter habitat could limit full production potential of the basin. Enter basin data below to check adequacy of winter habitat.
a. If mean winter temperature is ≥7 °C:

Habitat	Potential summer population		Area/ survival factor		Area needed (m^2)	Usable area (m^2)		Smolt factor		Smolts produced
Summer rearing	_______	X	0.6	=	______	____	X	0.9	=	_______
Winter rearing	_______	X	0.4	=	______	____	X	1.2	=	_______

If the usable area is less than habitat area needed, increase the usable area to meet needs. Use the column showing smolts produced to identify the most limiting habitat (that is, the habitat producing the fewest smolts). When summer and winter habitats are in balance in the present suboptimum configuration, consider increasing summer pool area to improve the habitat configuration 21

b. If mean winter temperature is <7 °C:

Habitat	Potential summer population	Area/ survival factor	Area needed (m^2)	Usable area (m^2)	Smolt factor	Smolts produced
Summer rearing	_______ x	0.6 =	________	________	x 0.4 =	_________
Winter rearing	_______ x	0.2 =	________	________	x 1.6 =	_________

If the usable area is less than habitat area needed, increase the usable area to meet needs. One or more habitat features might need to be increased. Use the column showing smolts produced to identify the most limiting habitat (that is, the habitat producing the fewest smolts). When summer and winter habitats are in balance in the present suboptimum configuration, consider increasing summer pool area to improve the habitat configuration 21

20. Summer habitat is >20 percent below carrying capacity. Spawning habitat, spring habitat, summer habitat, or winter habitat could limit the full production potential of the basin. Enter basin inventory data below to assess limiting factor(s).

a. If mean winter water temperature is ≥7 °C:

Habitat	Potential summer population	Area/ survival factor	Area needed (m^2)	Usable area (m^2)	Smolt factor	Smolts produced
Spawning	x	0.006 =	________	X____	95.5 =	_________
Spring rearing	X	0.3 =	________	X____	1.7 =	_________
Summer rearing	x	0.6 =	________	X____	0.9 =	_________
Winter rearing	x	0.4 =	________	X____	1.2 =	_________

If the usable area is less than habitat area needed, increase the usable area to meet needs. One or more habitat features might need to be increased. Use the column showing smolts produced to identify the most limiting habitat (that is, the habitat producing the fewest smolts). When summer and winter habitats are in balance in the present suboptimum configuration, consider increasing summer pool area to improve the habitat configuration 21

b. If mean winter water temperature is <7 °C:

Habitat	Potential summer population	Area/ survival factor	Area needed (m^2)	Usable area (m^2)	Smolt factor	Smolts produced
Spawning	__________ X	0.006 =	________	________	x 45.0 =	_________
Spring rearing	__________ X	0.3 =	________	________	X 0.8 =	_________
Summer rearing	__________ X	0.6 =	________	________	X 0.4 =	_________
Winter rearing	__________ X	0.2 =	________	________	X 1.6 =	_________

If the usable area is less than habitat area needed, increase the usable area to meet needs. One or more habitat features might need to be increased. Use the column showing smolts produced to identify the most limiting habitat (that is, the habitat producing the fewest smolts). When summer and winter habitats are in balance in the present suboptimum configuration, consider increasing summer pool area to improve the habitat configuration 21

21. If decision is to increase summer pool area, then estimate area of pools, glides, riffles, and side channels that will be present in summer after habitat manipulation is complete. Calculate potential summer coho salmon population using table below:
a. For hatchery supplementation

Area pools	x 0.6 fish/m^2	= ______.	
Area glides	x 0.3 fish/m^2	= ______.	
Area cobble-boulder riffles	x 0.2 fish/m^2	= ______.	
Area beaver ponds	x 0.5 fish/m^2	= ______.	
Area of pools in side channels	x 0.6 fish/m^2	= ______.	
Potential summer population		= ______	22

b. No hatchery supplementation

Area pools	x 1.7 fish/m2	= ______.	
Area glides	x 0.9 fish/m2	= ______.	
Area cobble-boulder riffles	x 0.4 fish/m^2	= ______.	
Area beaver ponds	x 1.3 fish/m^2	= ______.	
Area side-channels	x 1.7 fish/m^2	= ______.	
Potential summer population		=_______	22

22. Use potential summer population of coho salmon from 21 (above) to estimate spawning and spring rearing habitats needed to fill summer habitat with coho salmon parr and winter habitat needed to accommodate summer population. Habitat manipulations should achieve this balance.
a. If mean winter water temperature is $\geq$7 °C:

Habitat	Potential summer population		Area/survival factor		Area needed (m^2)
Spawning	____________	x	0.006	=	____________
Spring rearing	____________	x	0.3	=	____________
Summer rearing	____________	x	0.6	=	____________
Winter rearing	____________	x	0.4	=	____________

When needed habitat areas are achieved, areas in basin accessible to coho salmon are in balance and at full production. If some habitat in the basin is inaccessible, you may want to consider the productive potential of that habitat 23

b. If mean winter water temperature in <7 °C:

Habitat	Potential summer population		Area/survival factor	Area needed (m^2)
Spawning	___________	x	0.006	= _________
Spring rearing	___________	x	0.3	= _________
Summer rearing	___________	x	0.6	= _________
Winter rearing	___________	x	0.2	= _________

When needed habitat areas are achieved, areas in basin accessible to coho salmon are in balance and at full production. If some habitat in the basin is inaccessible, you may want to consider the productive potential of that habitat 23

23. Check the characteristics and productive potential of inaccessible habitat in the basin to see if (1) access should be provided and (2) subsequent habitat improvement is needed.

a. Some habitat with gradient ≤3 percent is inaccessible to coho salmon 24

b. Some habitat with gradient >3 percent is inaccessible to coho salmon. Habitat with gradient >3 percent is not preferred by coho salmon; consider emphasis of other salmonids (for example, cutthroat trout) in these habitats.

24. Habitat configuration.

a. ≥50 percent of wetted surface area in basin used by juvenile coho salmon in summer is in pools 25

b. <50 percent of wetted surface area in basin used by juvenile coho salmon in summer is in pools 27

25. Analyze habitats to assess potential for coho salmon rearing in summer. Potential in present configuration is:

Area pools	x	1.7 fish/m^2	= __________.
Area glides	x	0.9 fish/m^2	= __________.
Area cobble-boulder riffles	x	0.4 fish/m^2	= __________.
Area beaver ponds	x	1.3 fish/m^2	= __________.
Area side-channels	x	1.7 fish/m^2	= __________.
Potential summer population			= __________ 26

26. Potential limiting factors.

a. If mean winter water temperature is ≥7 °C:

Habitat	Potential summer population		Area/ survival factor	Area needed (m^2)	Usable area (m^2)		Smolt factor	Smolts produced
Spawning	_______	x	0.006	=_____	______	x	95.5 =	______
Spring rearing	_______	x	0.3	=_____	______	x	1.7 =	______
Summer rearing	_______	x	0.6	=_____	______	x	0.9 =	______
Winter rearing	_______	x	0.4	=_____	______	x	1.2 =	______

If the usable area is less than habitat area needed, increase the usable area to meet needs. One or more habitat features might need to be increased. Use the column showing smolts produced to identify the most limiting habitat (that is, the habitat producing the fewest smolts).

b. If mean winter water temperature is <7 °C:

Habitat	Potential summer population		Area/ survival factor	Area needed (m^2)	Usable area (m^2)		Smolt factor	Smolts produced
Spawning	_______	x	0.006	=_____	______	x	45.0 =	______
Spring rearing	_______	x	0.3	=_____	______	x	0.8 =	______
Summer rearing	_______	x	0.6	=_____	______	x	0.4 =	______
Winter rearing	_______	x	0.2	=_____	______	x	1.6 =	______

If the usable area is less than habitat area needed, increase present area to meet needs. Two or more habitats might need to be increased. Use the smolts produced column to identify the most limiting habitat (that is, the habitat producing the fewest smolts).

27. Analyze habitats to assess potential for coho salmon rearing in summer. Potential in present configuration is:

Area pools	x	0.6 fish/m^2	= ________.
Area glides	x	0.3 fish/m^2	= ________.
Area cobble-boulder riffles	x	0.2 fish/m^2	= ________.
Area beaver ponds	x	0.5 fish/m^2	= ________.
Area of pools in side channels	x	0.6 fish/m^2	= ________.
Potential summer population			= _________

28. Potential limiting factors.

a. If mean winter water temperature is ≥7 °C:

Habitat	Potential summer population	Area/ survival factor	Area needed (m^2)	Usable area (m^2)	Smolt factor	Smolts produced
Spawning	_______ x	0.006	=_____	______ x	95.5 =	______
Spring rearing	_______ x	0.3	=_____	______ x	1.7 =	______
Summer rearing	_______ x	0.6	=_____	______ x	0.9 =	______
Winter rearing	_______ x	0.4	=_____	______ x	1.2 =	______

If the usable area is less than habitat area needed, increase present area to meet needs. Two or more habitats might need to be increased. Use the smolts produced column to identify the most limiting habitat (that is, the habitat producing the fewest smolts). When habitats are in balance with present suboptimum summer configuration, consider increasing summer pool area to improve the habitat configuration 29

b. If mean winter water temperature is <7 °C:

Habitat	Potential summer population	Area/ survival factor	Area needed (m^2)	Usable area (m^2)	Smolt factor	Smolts produced
Spawning	_______ x	0.006	=_____	______ x	45.0 =	______
Spring rearing	_______ x	0.3	=_____	______ x	0.8 =	______
Summer rearing	_______ x	0.6	=_____	______ x	0.4 =	______
Winter rearing	_______ x	0.2	=_____	______ x	1.6 =	______

If the usable area is less than habitat area needed, increase present area to merit needs. Two or more habitats might need to be increased. Use the smolts produced column to identify the most limiting habitat (that is, the habitat producing the fewest smolts). When habitats are in balance with the present suboptimum summer configuration, consider increasing summer pool area to improve the habitat configuration 29

29. If decision is to increase summer pool area, then estimate area of pools, glides, riffles, and side channels that will be present in summer after habitat manipulation is complete. Calculate potential summer coho salmon population using table below:

Area pools	x	0.6 fish/m^2	= _______.
Area glides	x	0.3 fish/m^2	= _______.
Area cobble-boulder riffles	x	0.2 fish/m^2	= _______.
Area beaver ponds	x	0.5 fish/m^2	= _______.
Area of pools in side channels	x	0.6 fish/m^2	= _______.
Potential summer population			= ________

30

30. Use potential summer population of coho salmon from 29 (above) to estimate spawning and spring rearing habitats needed to fill summer habitat with coho salmon parr, and winter habitat needed to accommodate summer population. Habitat manipulations should achieve this balance.

a. If mean winter water temperature in ≥7 C:

Habitat	Potential summer population		Area/survival factor	Area needed (m^2)
Spawning	___________	x	0.006	= _________
Spring rearing	___________	x	0.3	= _________
Summer rearing	___________	x	0.6	= _________
Winter rearing	___________	x	0.4	= _________

b. If mean winter water temperature in <7 °C:

Habitat	Potential summer population		Area/survival factor	Area needed (m^2)
Spawning	___________	x	0.006	= _________
Spring rearing	___________	x	0.3	= _________
Summer rearing	___________	x	0.6	= _________
Winter rearing	___________	x	0.2	= _________

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Appendix 1 Habitat equivalent coefficients for estimating the amount of "usable habitat."

A. Early rearing habitat

Habitat type	Coefficient
Backwater pool	1.0
Sidechannel pool	1.0
Beaver pond	.6
Glides	.4
Straight and lateral scour pool	.2
Trench pool	.2
Plunge pool	.2
Riffle	.2
Rapid	.1

B. Winter habitat

1. Mean winter water temperature $\geq$7 °C

Habitat Type	Coefficient
Beaver pond <500 m^2	1.0
Backwater pool	1.0
Lateral scour pool $\geq$100cm	.8
Beaver pond >500 m^2	.5
Dam pool	.5
Lateral scour pool 70-100 cm	.3

2. Mean winter water temperature < 7°C

Habitat Type	Coefficient
Beaver pond <500m^2	1.0
Backwater pool	.7
Beaver pond >500m^2	.5

The usable habitat is the sum of the given habitat types times the corresponding coefficient.

Appendix 2 Coho habitat and smolt factors for limiting-factors analysis.

Basic data:

Density Independent Survival Rates	egg to emergent fry	0.33
	fry to June parr	.78
	June to September	.84
	Sept. to beginning of winter	.80
	≥7 °C Sept. to March	.53
	<7 °C Sept. to March	.25
	≥7 °C beginning winter to March	.66
	<7 °C beginning winter to March	.31

Rearing Densities:

833 eggs/m^2 (based on 2500 eggs/redd and 3 m^2/redd)
5.0 fry/m^2
1.7 summer parr/m^2
1.8 winter parr/m^2 at ≥7 °C
5.0 winter parr/m^2 at <7 °C

Equations:

Area/Survival Factor (A/SF) = m^2 needed to produce or support the potential summer population

For life history stages before summer:

A/SF = 1/((Density at that stage) * (Survival from that stage to summer))
Spawning A/SF = 1/ (833 * -0.33 * 0.78 * 0.84) = 0.006
Spring A/SF = 1/(5.0 * 0.78 * 0.84) = 0.3

For summer:

A/SF = 1/(Summer parr density) = 1/1.7 = 0.6

For winter:

A/SF = (1/Winter density) * Survival from September to beginning of winter
A/SF (≥7 °C) = (1/1.8) * 0.80 = 0.4
A/SF (<7 °C) = (1/5.0) * 0.80 = 0.2

Smolt Factor (SF) = The number of smolts that should be produced by one unit of habitat for a particular life history stage.

SF = Density at a stage * survival from that stage to smolt
Winter temperature $\geq$7 °C:
Spawning SF = 833 * 0.33 * 0.78 * 0.84 * 0.53 = 95.5
Spring SF = 5.0 * 0.78 * 0.84 * 0.53 = 1.7
Summer SF = 1.7 * 0.53 = 0.9
Winter SF = 1.8 * 0.66 = 1.2

Winter temperature <7 °C
Spawning SF = 833 * 0.33 * 0.78 * 0.84 * .25 = 45.0
Spring SF = 5.0 * 0.78 * 0.84 * 0.25 = 0.8
Summer SF = 1.5 * 0.25 = 0.4
Winter SF = 5.0 * 0.31 = 1.6

Reeves, Gordon H.; Everest, Fred H.; NIckelson, Thomas E. 1989. Identification of physical habitats limiting the production of coho salmon in western Oregon and Washington. Gen. Tech. Rep. PNW-GTR-245. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 18 p.
Fishery managers are currently spending millions of dollars per year on habitat enhancement for anadromous salmonids but often do not have the tools needed to ensure success. An analysis of factors limiting production of salmonids in streams must be completed before any habitat-enhancement program is begun. This paper outlines the first formal procedure for identifying physical habitats limiting production of coho salmon.
Keywords: Coho salmon, limiting factors, dichotomous key.

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