

LIMNOLOGÍA



LICENCIATURA EN GESTIÓN AMBIENTAL
CURE/Facultad de Ciencias
Udelar
Reservorios - Represas - Embalses
goyenola@gmail.com
Maldonado, 2014

Represa, embalse / Pantano (España) / *Reservoir, dam, impoundment*

RESERVORIOS

Cuerpos de agua contruidos o modificados por la actividad humana para propósitos específicos, con el objetivo de proveer un recurso seguro y controlable.

Principales usos:

- Suministro de agua para potabilización
- Suministro para la actividad industrial (enfriamiento, etc.)
- Generación hidroeléctrica
- Riego, cría de ganado
- Regulación de cursos de agua y control de inundaciones
- Recreación, actividades náuticas y otros usos recreacionales
- Disposición de residuos
- Pesquerías comerciales y recreacionales
- Navegación

i\$!

¿UY?

Thornton, J., A. Steel & W. Rast, 1996. Chapter 8. Reservoirs. In Chapman, D. (ed) Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring. 2nd. UNESCO/WHO/UNEP.
http://www.who.int/water_sanitation_health/resourcesquality/wqachapter8.pdf



OSE, Aguas Corrientes



OSE, Paso Severino

Laguna del Sauce



San Francisco (Minas)



San Francisco (Minas)

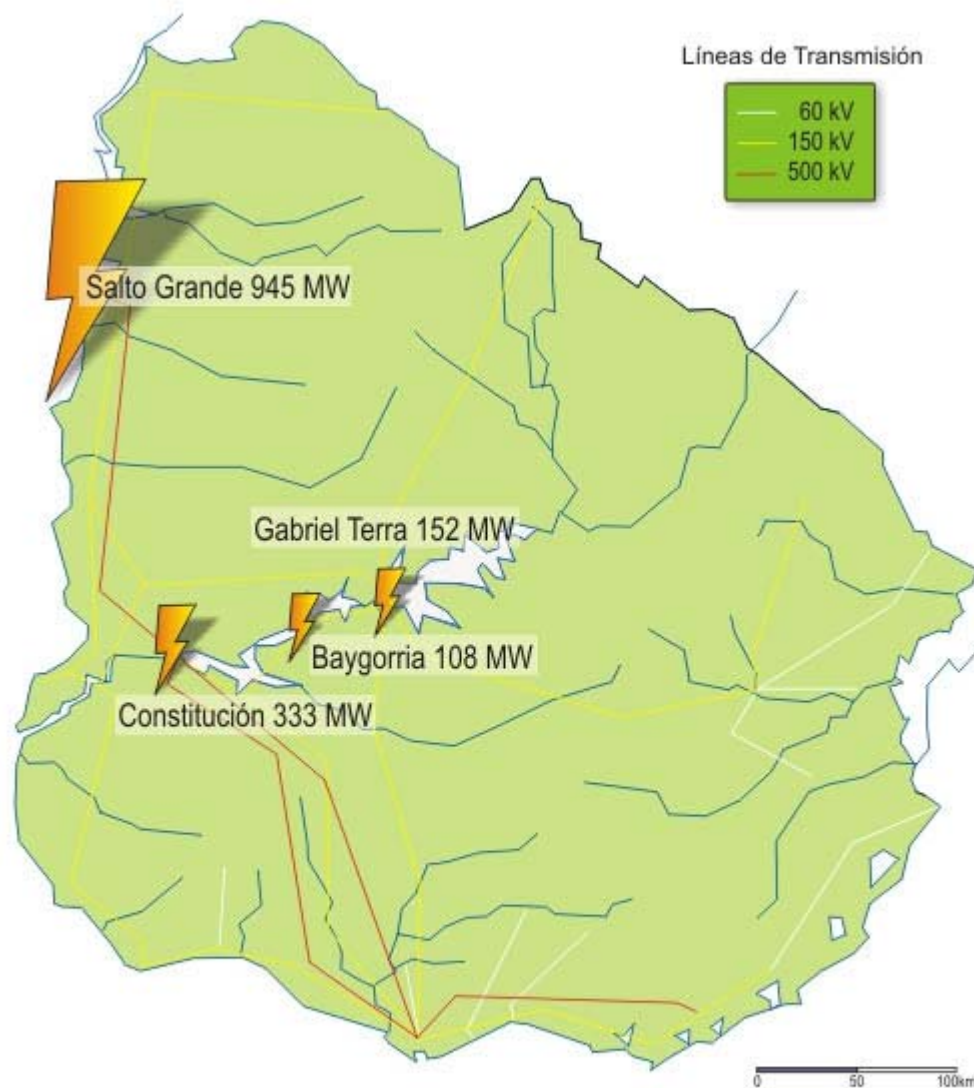


Represa de Cuñapirú (1882)



Salto Grande



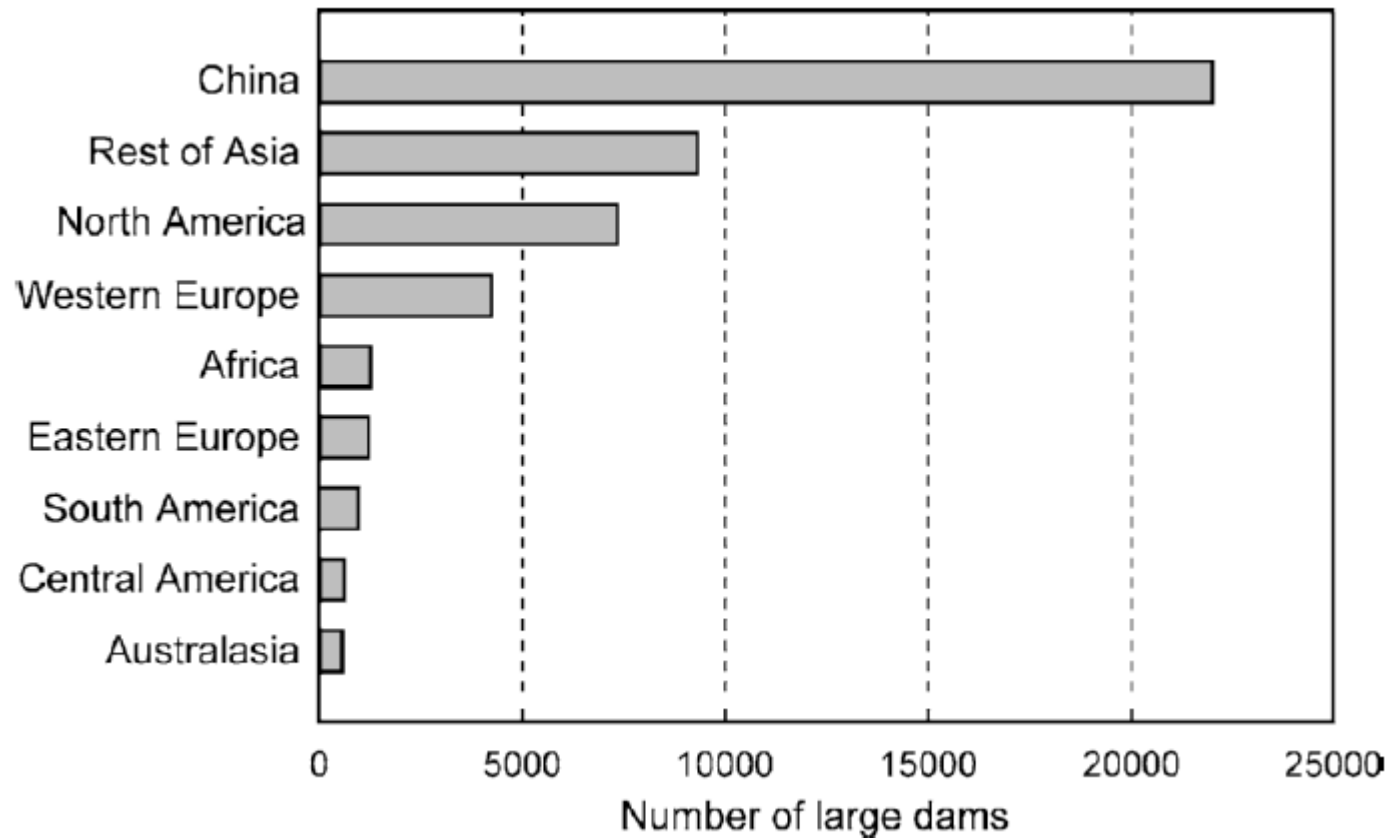


Centrales Hidroeléctricas

Capacidad Instalada y Líneas de Transmisión

Fuentes: Achkar (2000) y UTE



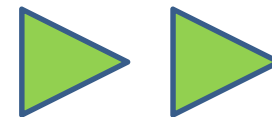


Allan, J. D. & M. M. Castillo, 2007. Stream Ecology: structure and function of running waters. Springer.

25 per cent of all waters flowing to the oceans have previously been impounded in reservoirs (UNEP, 1991).

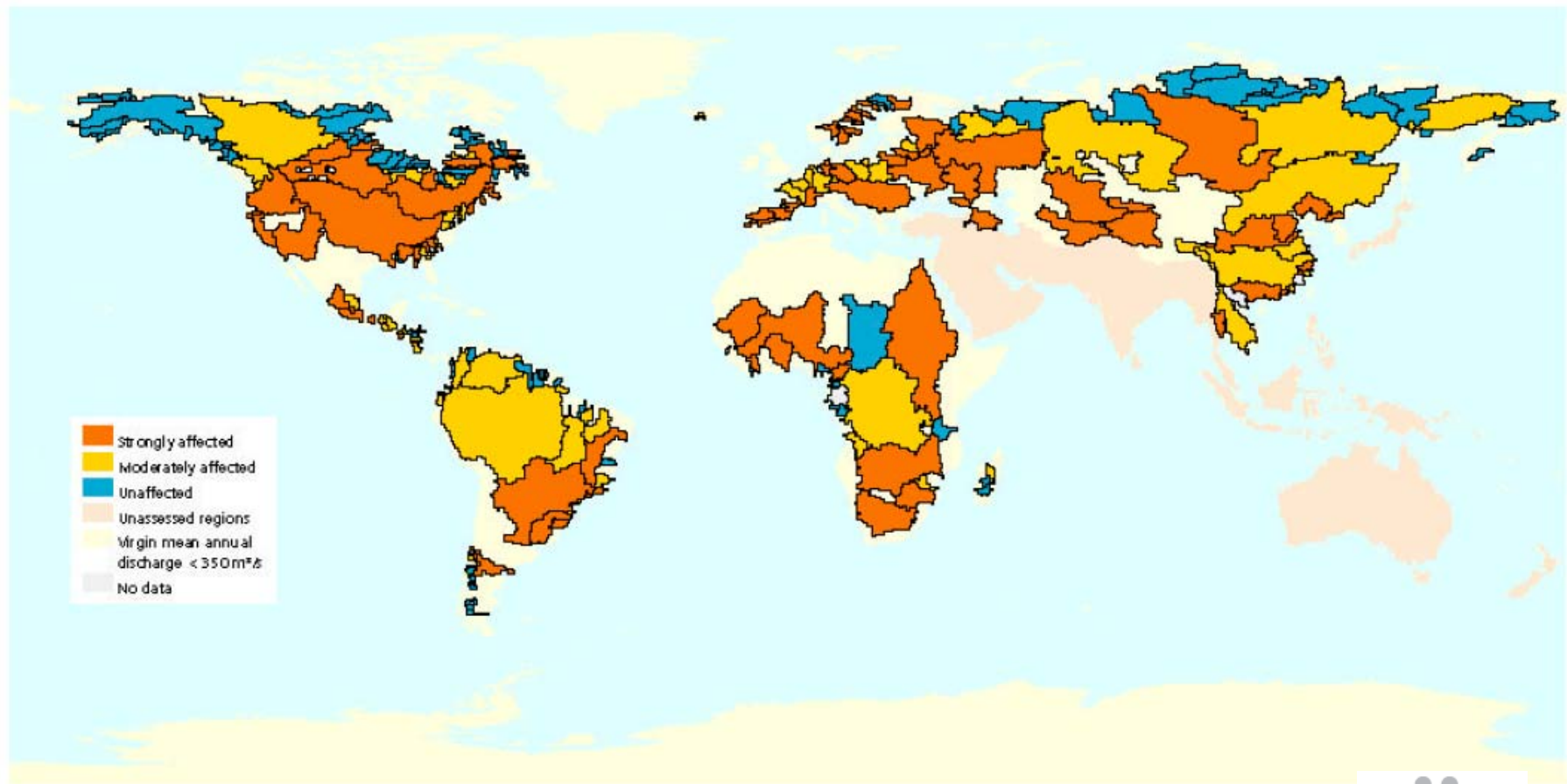
(Thornton et al 1996)

<http://www.youtube.com/watch?v=OR5IFcSsaxY#t=12>
<http://www.youtube.com/watch?v=RPm9LUZDCgg>



Map 1

River Channel Fragmentation and Flow Regulation



Source: Dynesius and Nilsson, 1994 and Nilsson et al., 2000. Watershed boundaries are from Fekete et al., 1999.

Projection: Geographic

América Latina

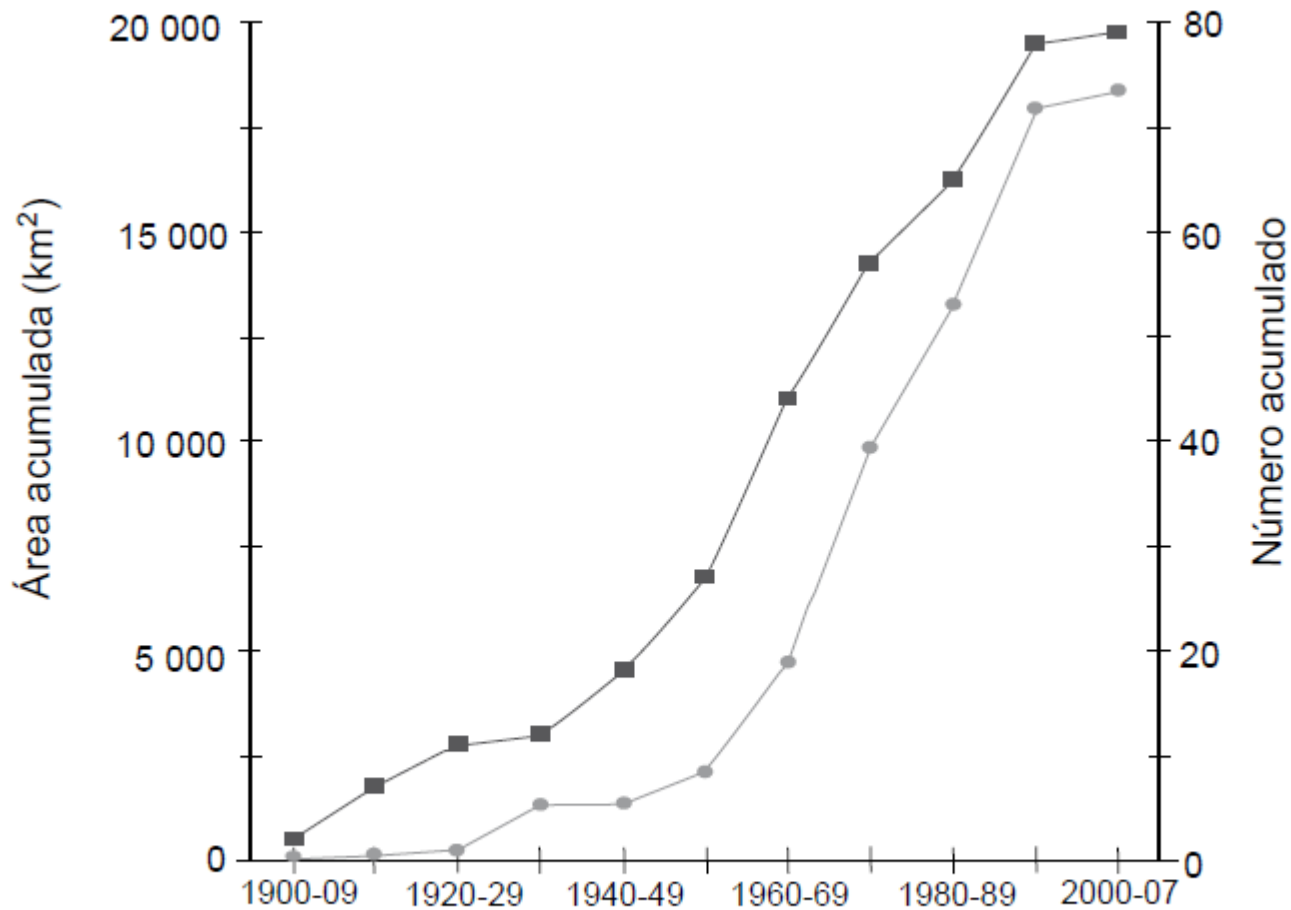
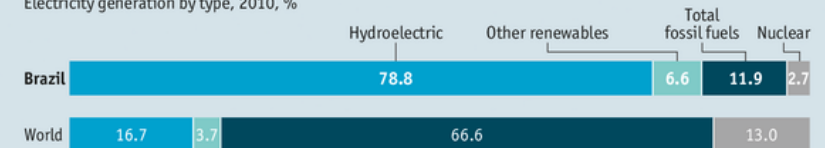


Figura 16.1. Área cubierta por los embalses(■) y número de represas (●) construidas en Brasil (adaptado de Agostinho *et al.*, 2007a).



Dam good

Electricity generation by type, 2010, %



Source: EIA

Figure 1 – Distribution of the main hydroelectric power plants in Brazil. Notice the concentration in the South and Southeast regions (Kelman et al., 2006).

*We All Live
Downstream*



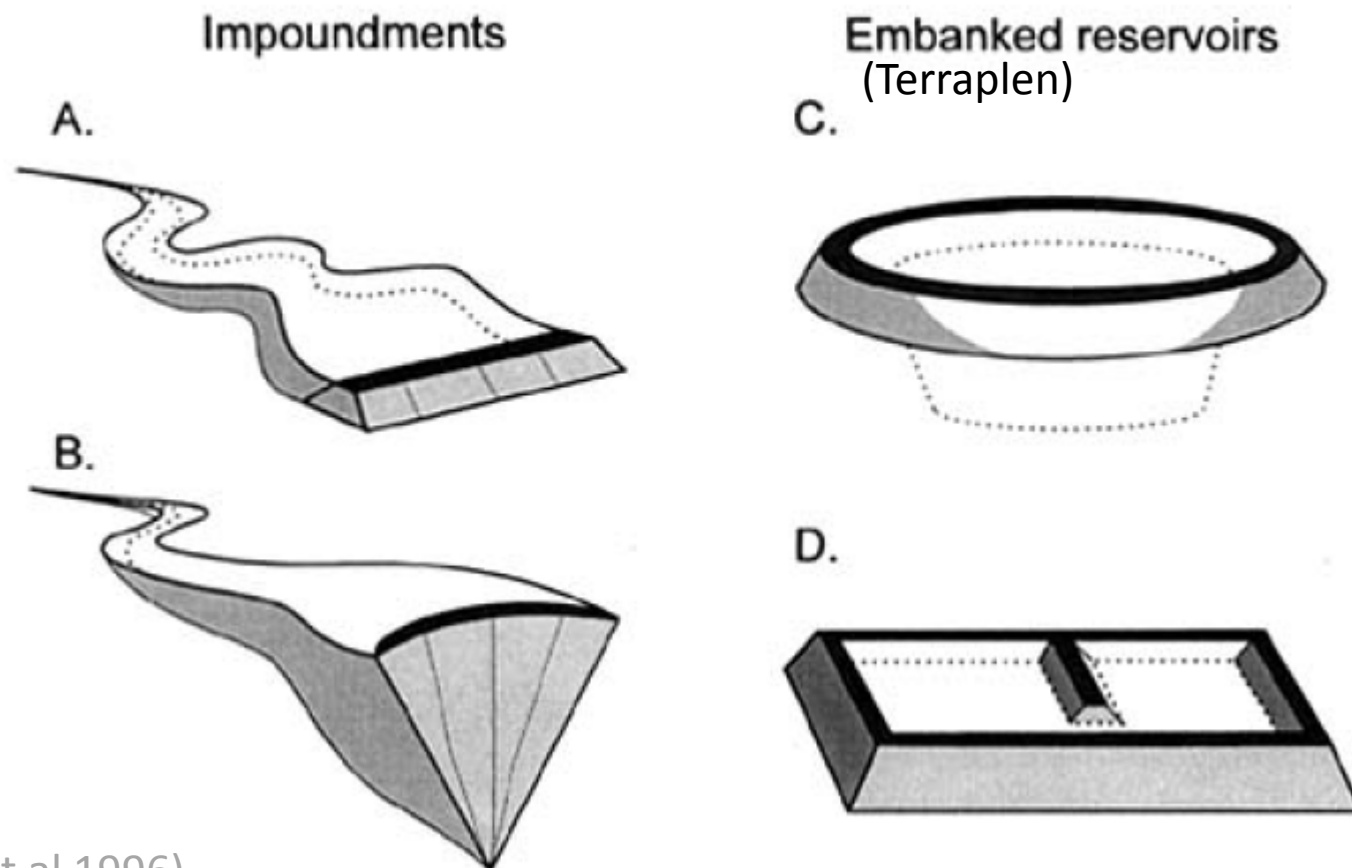


Hoover Dam (USA)

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RESERVORIOS

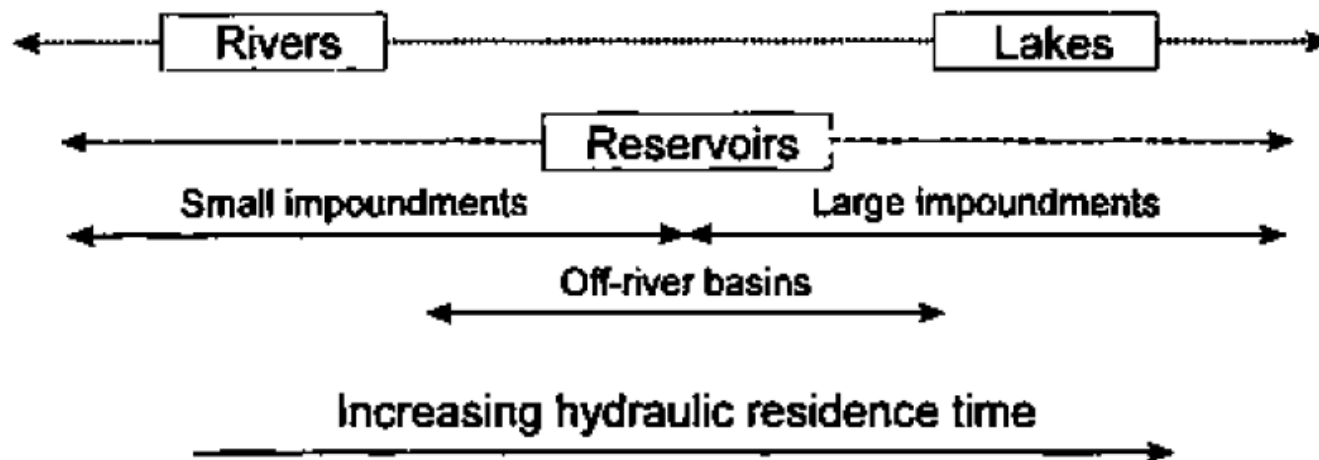
Figure 8.3 Examples of the principal reservoir configurations: A. shallow, 'U' shaped; B. deep, 'V' shaped; C. deep, regular; D. shallow, regular



(Thornton et al 1996)

Características

**Figure 8.2 The intermediate position of reservoirs between rivers and natural lakes is determined by their water residence time and degree of riverine influence
(Based on Kimmel and Groeger, 1984)**



(Thornton et al 1996)

Table 1.1 Characteristics of reservoirs and glacial lakes^a

Factor	Characteristic	
	Reservoir	Glacial lake
Shoreline	Astatic	Stable
Water level	Large, irregular fluctuations	Natural
Flushing rate	High	Low
Thermal stratification	Irregular	Natural regime, dimictic
Ionic composition	Variable	Relatively predictable
Sedimentation rate	High	Low
Turbidity	High	Low
Water release level	Variable	Surface
Organic accumulation	Rapid	Slow
Principal source of nutrients	Allochthonous, then autochthonous	Autochthonous
Growth selection	Rapid (r)	Homeostatic (K)
Immigration-extinction	Rapid	Slow

^aModified from Ryder 1978.

(Thornton et al 1996)

Dinámica / zonación

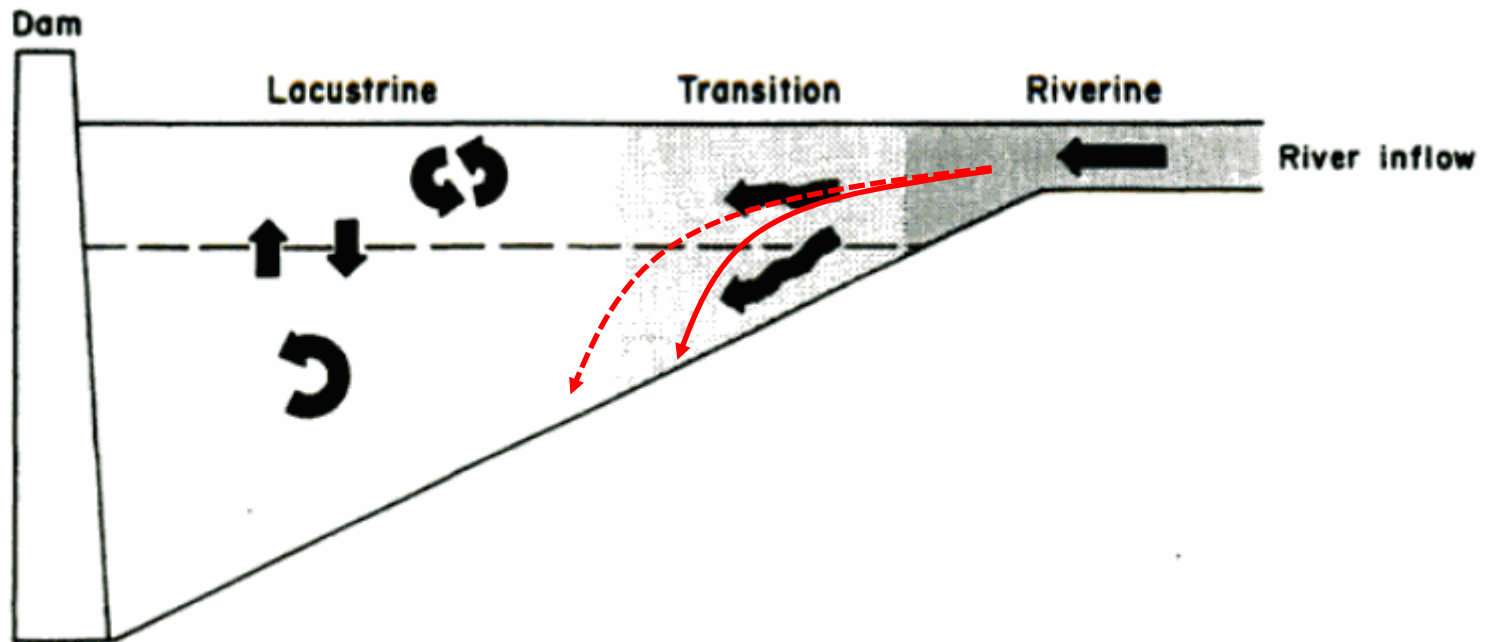
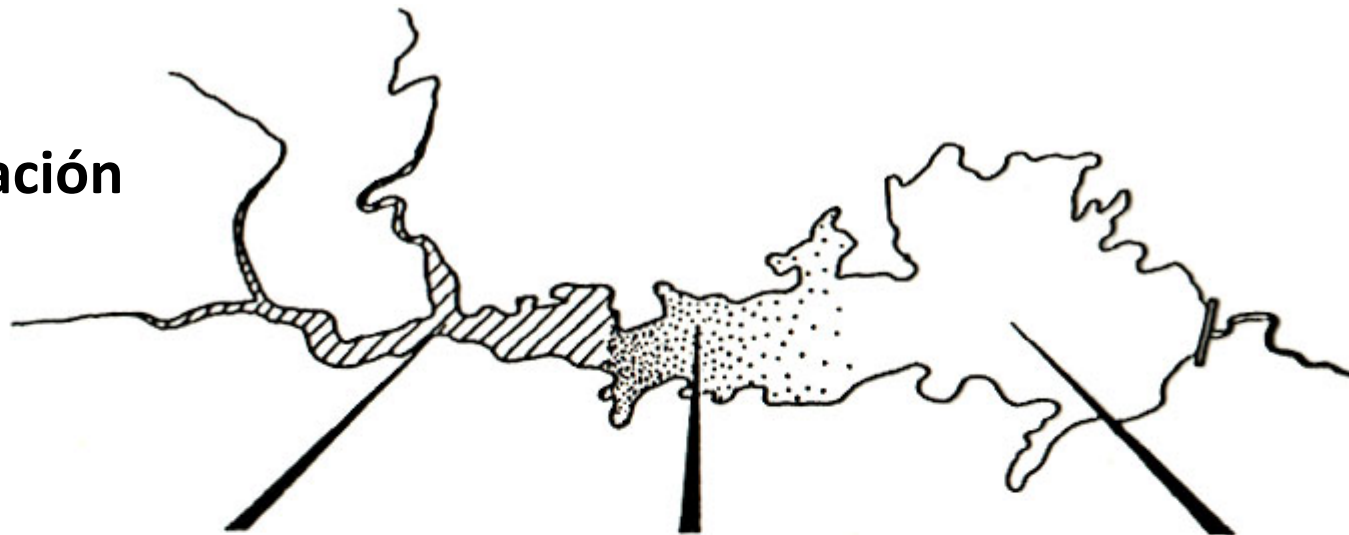


Figure 1.10 Three distinct zones resulting from gradients in reservoirs.

(Thornton et al 1996)

Zonación



RIVERINE ZONE

- NARROW, CHANNELIZED BASIN
- RELATIVELY HIGH FLOW
- HIGH SUSP. SOLIDS, TURBID, LOW LIGHT AVAIL., $Z_p < Z_m$
- NUTRIENT SUPPLY BY ADVECTION, REL. HIGH NUTRIENTS
- LIGHT-LIMITED PPR
- CELL LOSSES PRIMARILY BY SEDIMENTATION
- ORGANIC MATTER SUPPLY PRI. ALLOCHTHONOUS, $P < R$
- MORE "EUTROPHIC"

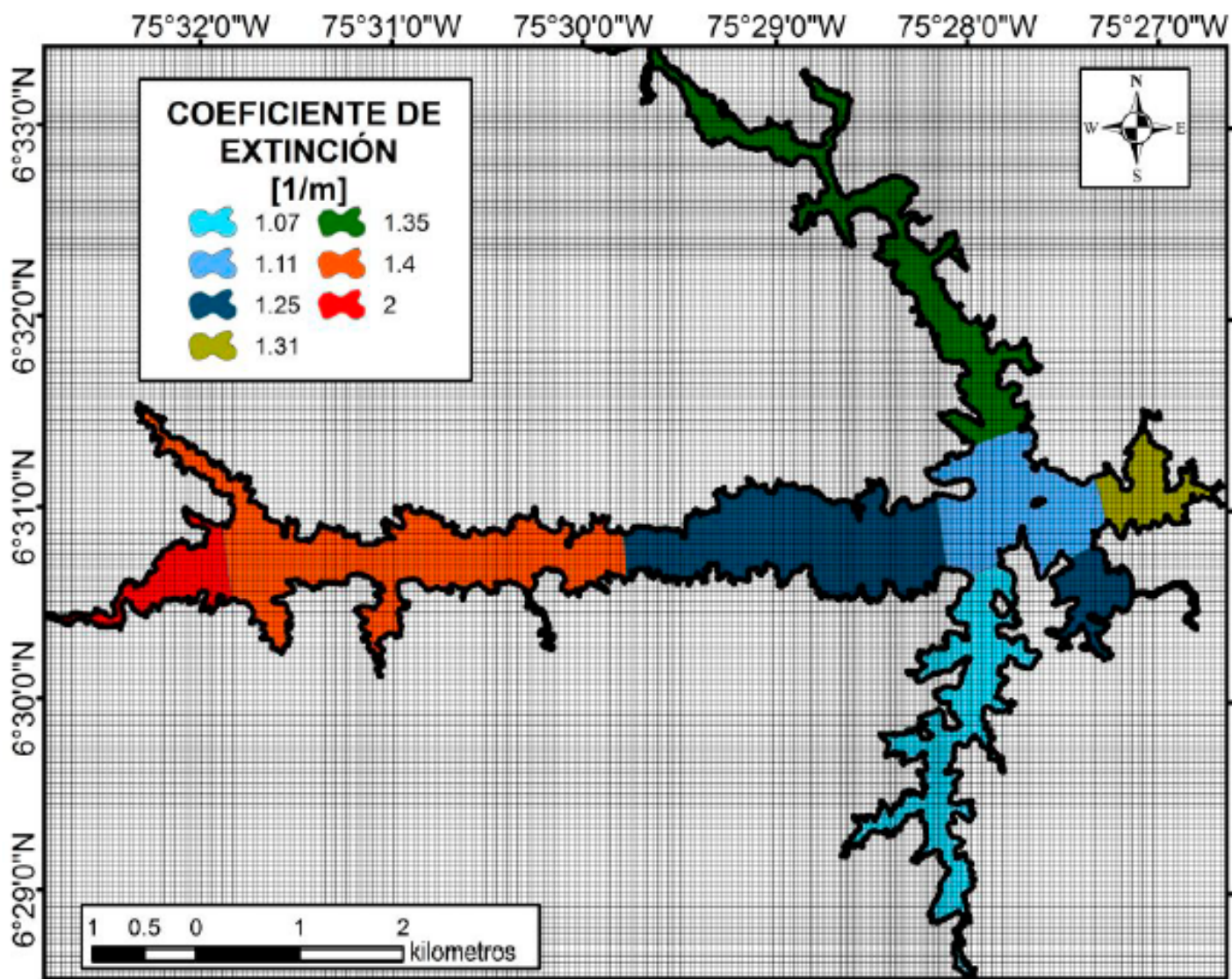
TRANSITIONAL ZONE

- BROADER, DEEPER BASIN
- REDUCED FLOW
- REDUCED SUSP. SOLIDS, LESS TURBID, LIGHT AVAIL. INCREASED
- ADVECTIVE NUTRIENT SUPPLY REDUCED
- PPR/m^3 REL. HIGH
- CELL LOSSES BY SEDIMENTATION AND GRAZING
- INTERMEDIATE
- INTERMEDIATE

LACUSTRINE ZONE

- BROAD, DEEP, LAKE-LIKE BASIN
- LITTLE FLOW
- REL. CLEAR, LIGHT MORE AVAIL. AT DEPTH, $Z_p > Z_m$
- NUTRIENT SUPPLY BY INTERNAL RECYCLING, REL. LOW NUTRIENTS
- NUTRIENT-LIMITED PPR
- CELL LOSSES PRIMARILY BY GRAZING
- ORGANIC MATTER SUPPLY PRIMARILY AUTOCHTHONOUS, $P > R$
- MORE "OLIGOTROPHIC"

(Thornton et al 1996)



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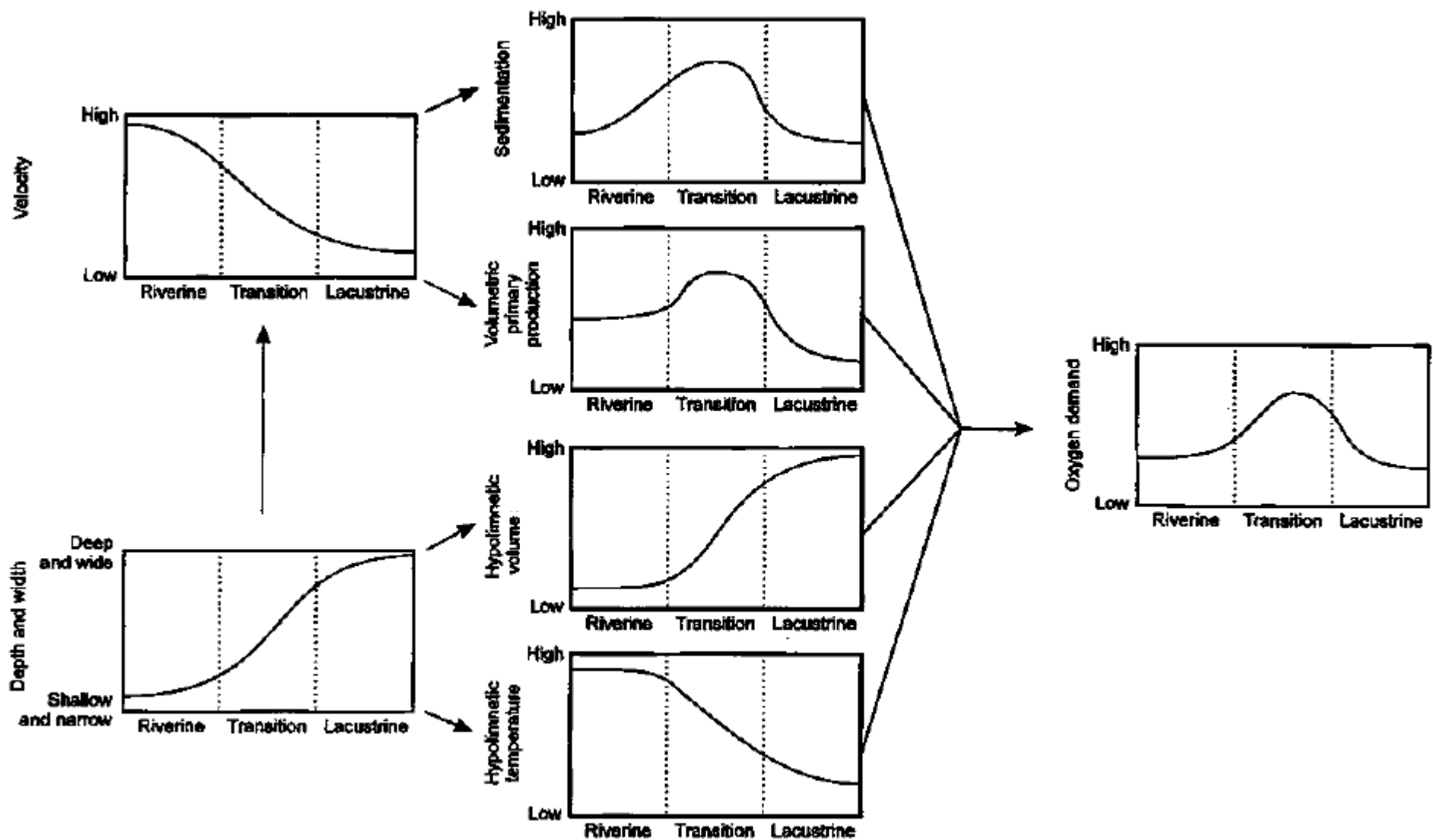
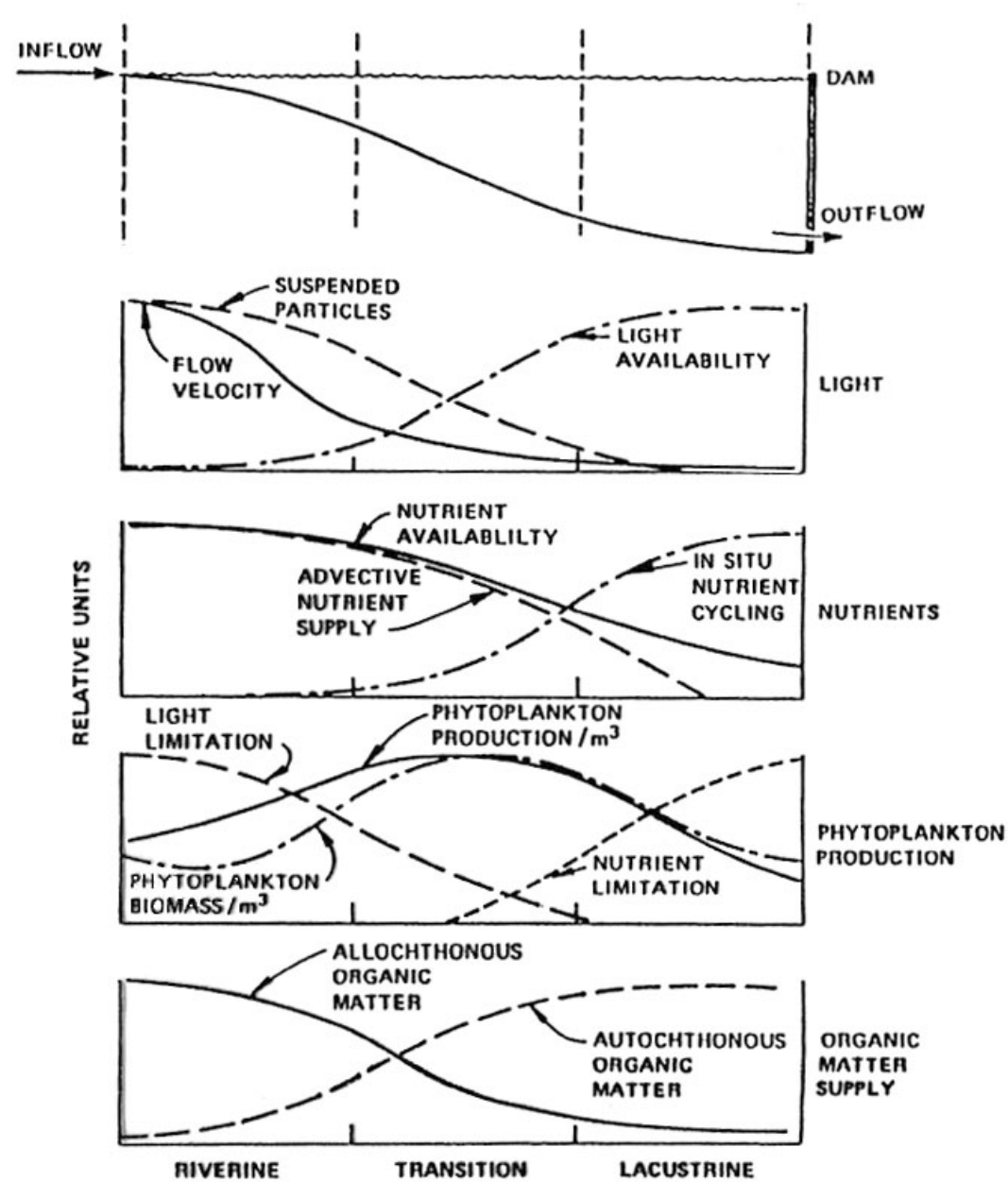


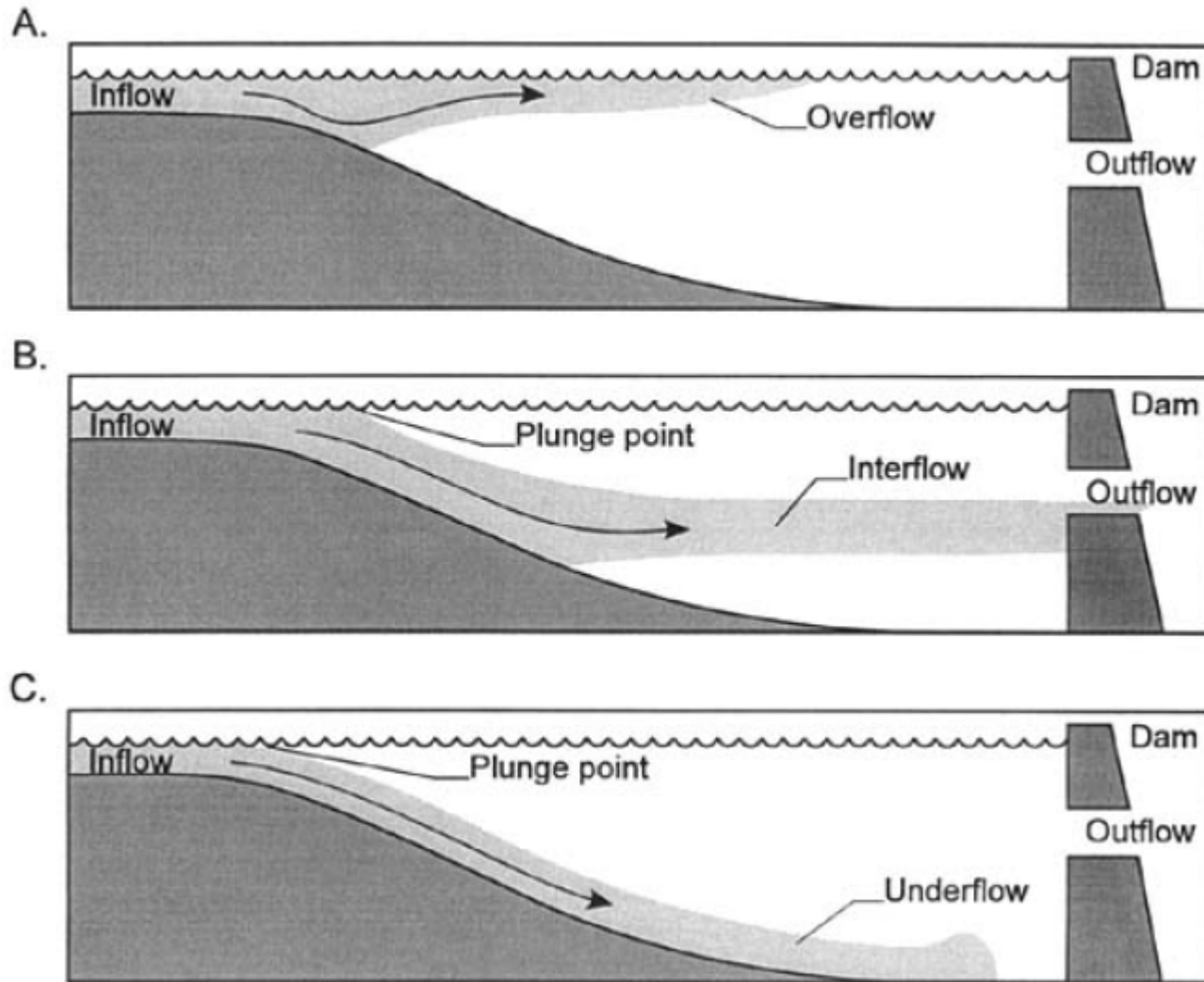
Figure 8.10 Relationship of morphometry, retention time and longitudinal variation in water quality process rates to oxygen demand along the length of a reservoir (see also Figure 8.4) (After Cole and Hannan, 1990) Reproduced by permission of John Wiley & Sons, Inc.

(Thornton et al 1996)

Zonación



(Thornton et al 1996)



(Thornton et al 1996)

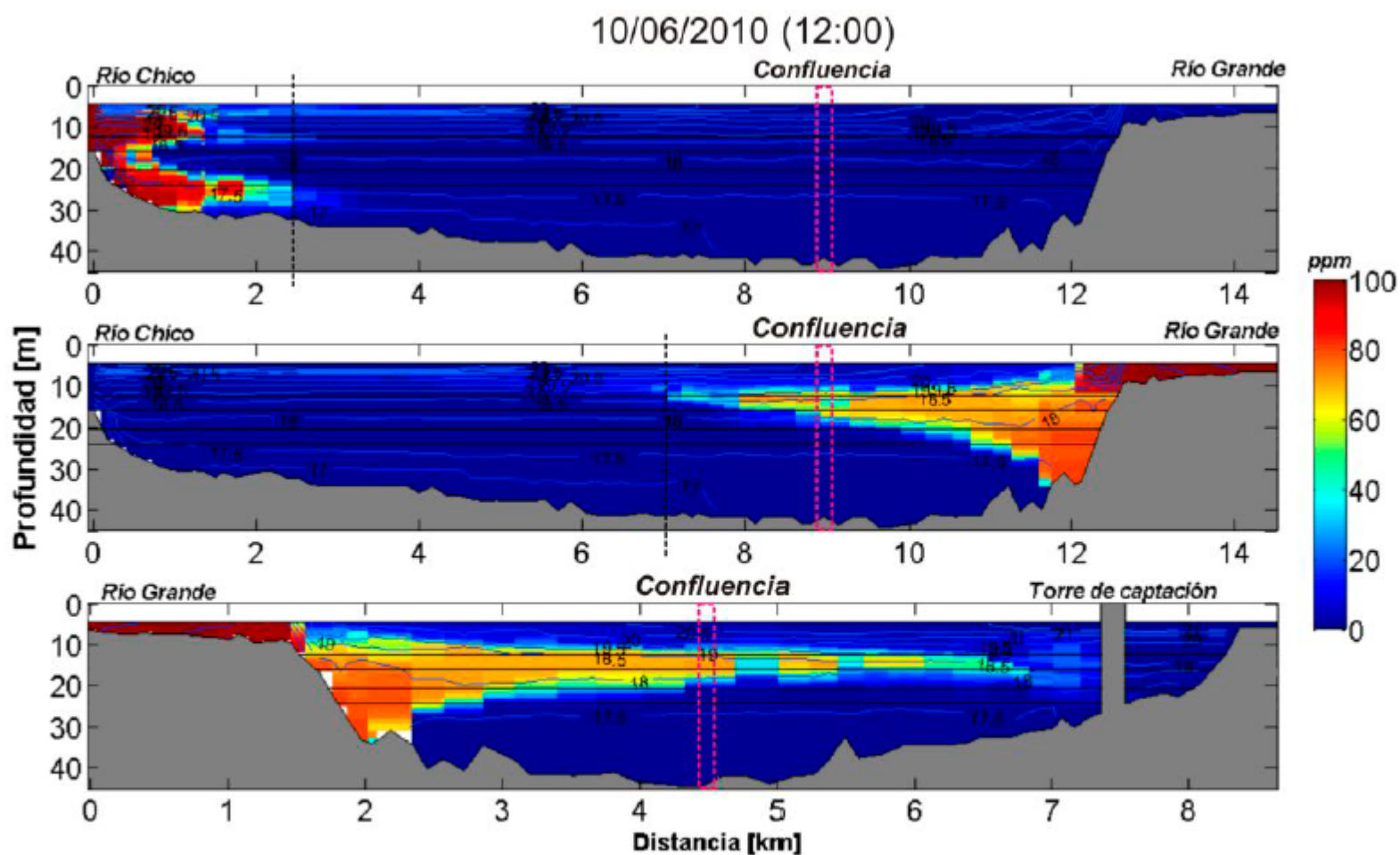
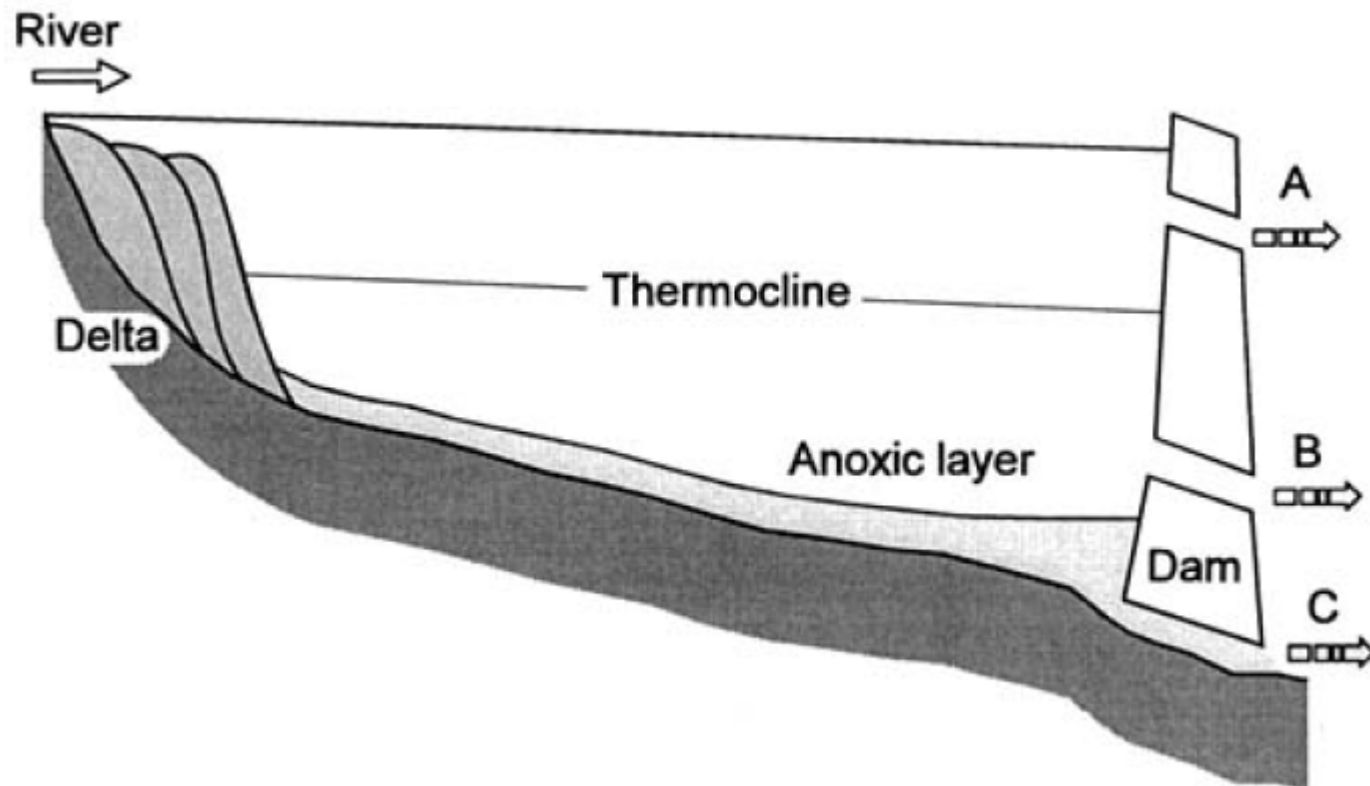
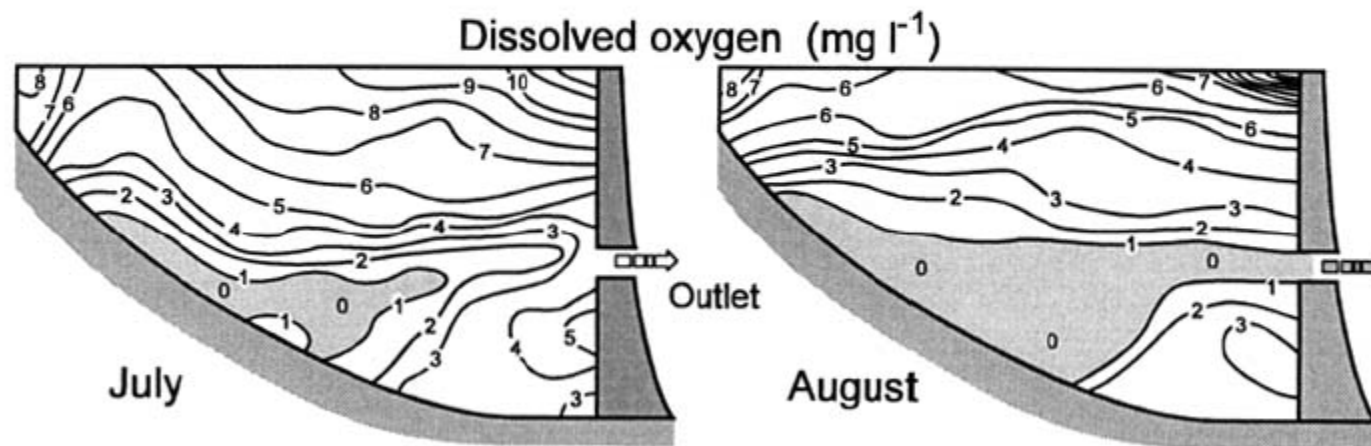


Figura 5-14: Desarrollo de la entrada de las plumas de los ríos Grande y Chico en el embalse Riogrande II - Caso de simulación con el embalse en condición de nivel medio e hidrográficas sincronizadas.



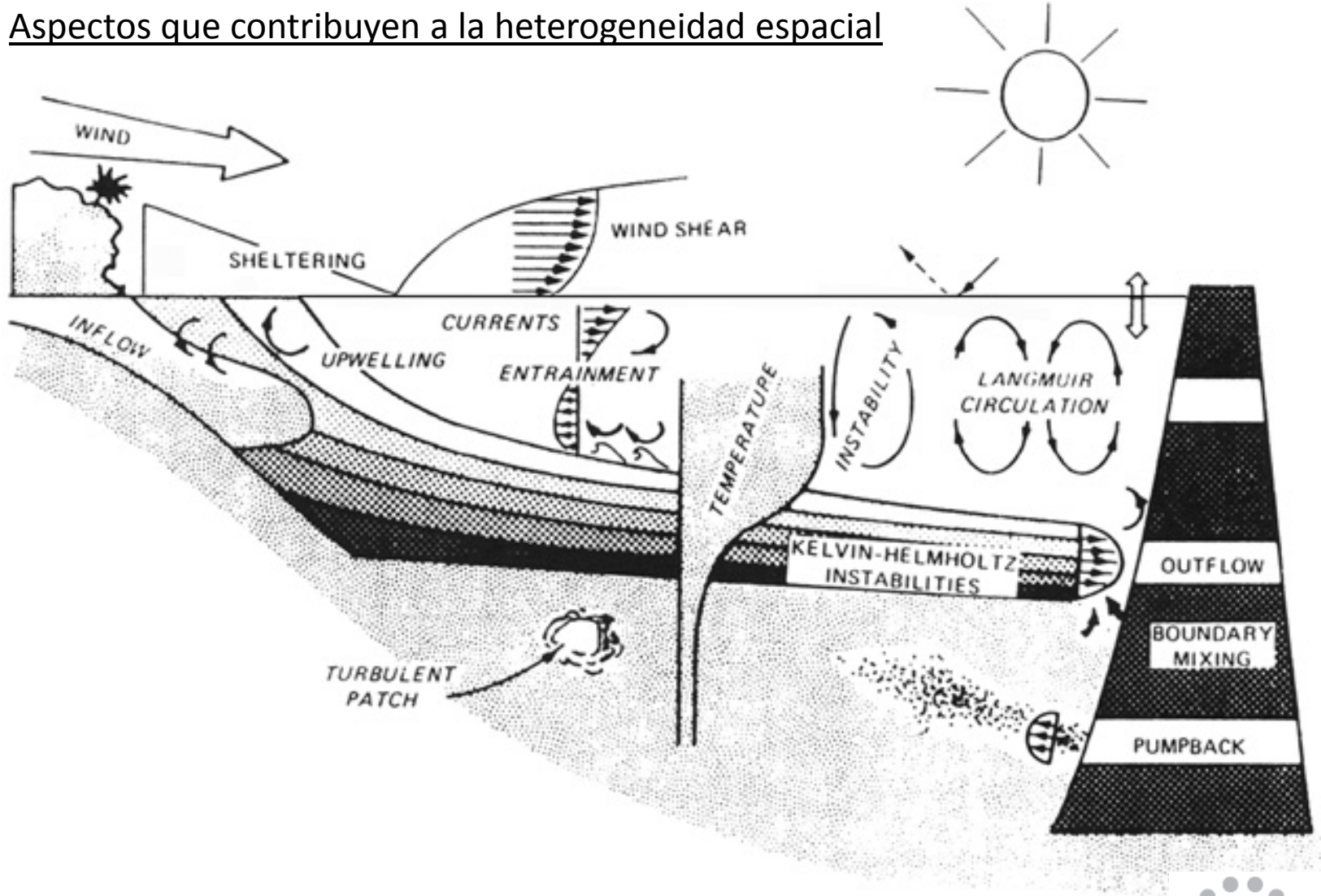
(Thornton et al 1996)

Figure 8.11 An example of modifications in the depth distribution of dissolved oxygen by currents caused by mid-depth water withdrawal (Based on Ebel and Koski, 1968)



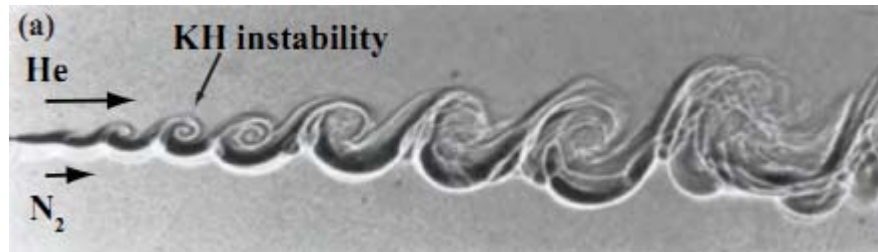
(Thornton et al 1996)

Aspectos que contribuyen a la heterogeneidad espacial

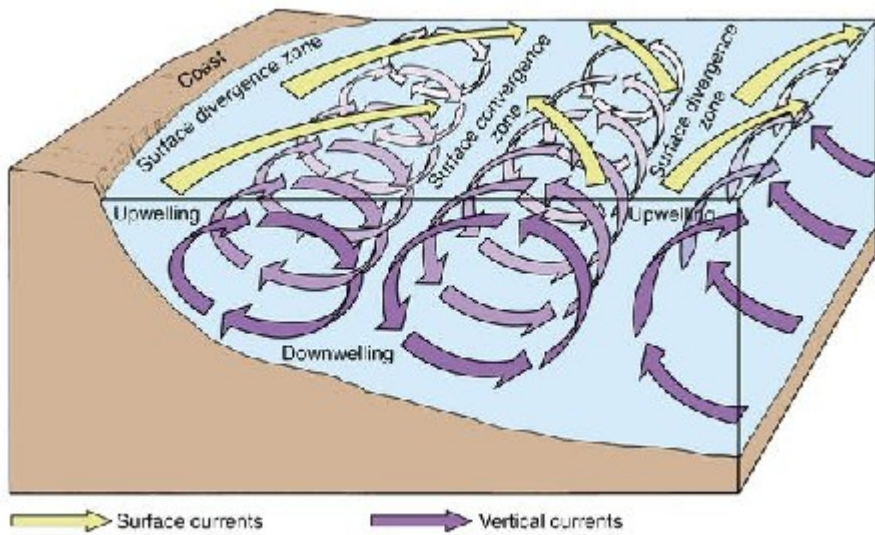


(Thornton et al 1996)

Apunte: Inestabilidad de Kelvin-Helmholtz



Apunte: Circulación de Langmuir



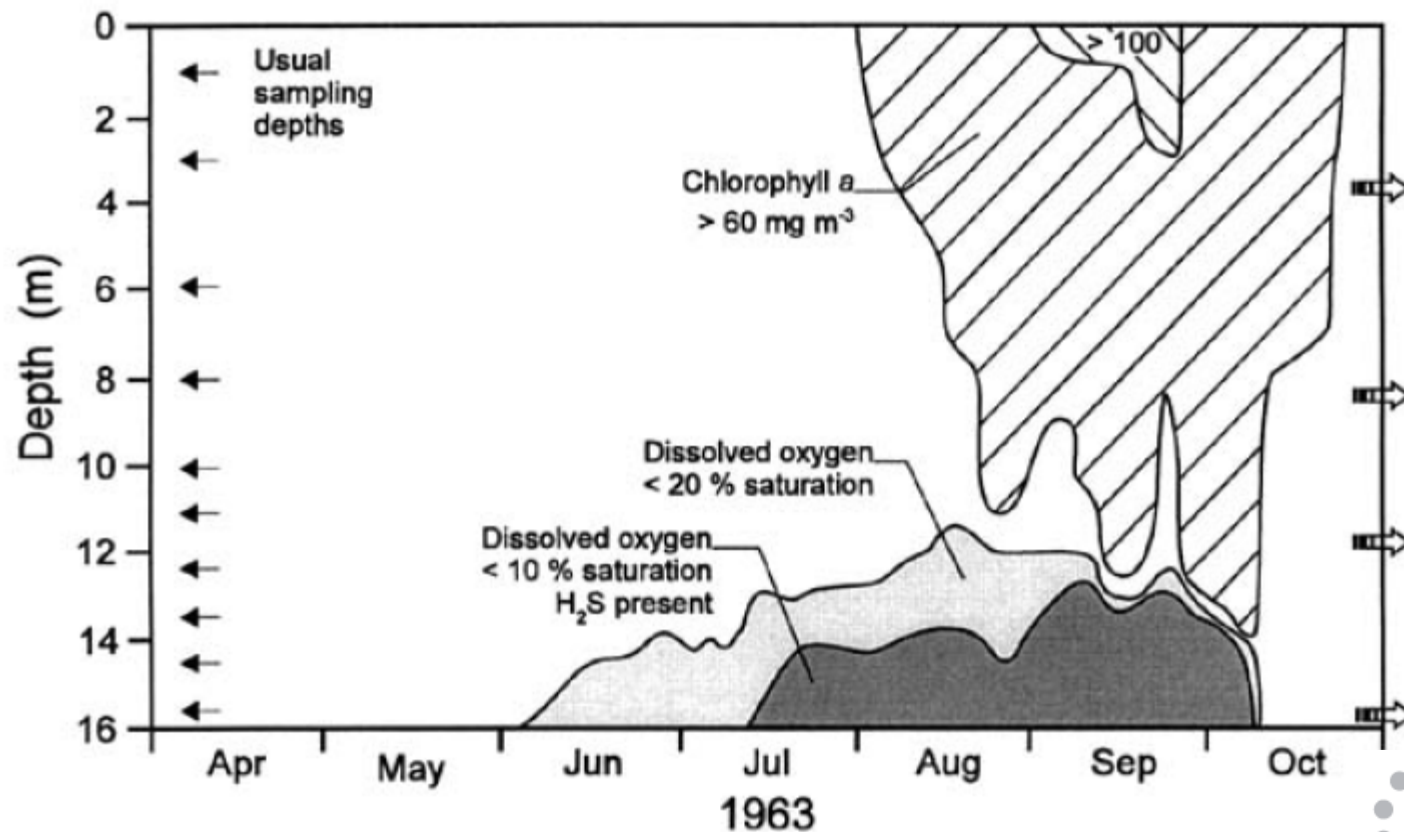
¿Cuáles serán los productores primarios predominantes?



Lago Rincón del Bonete (2013)

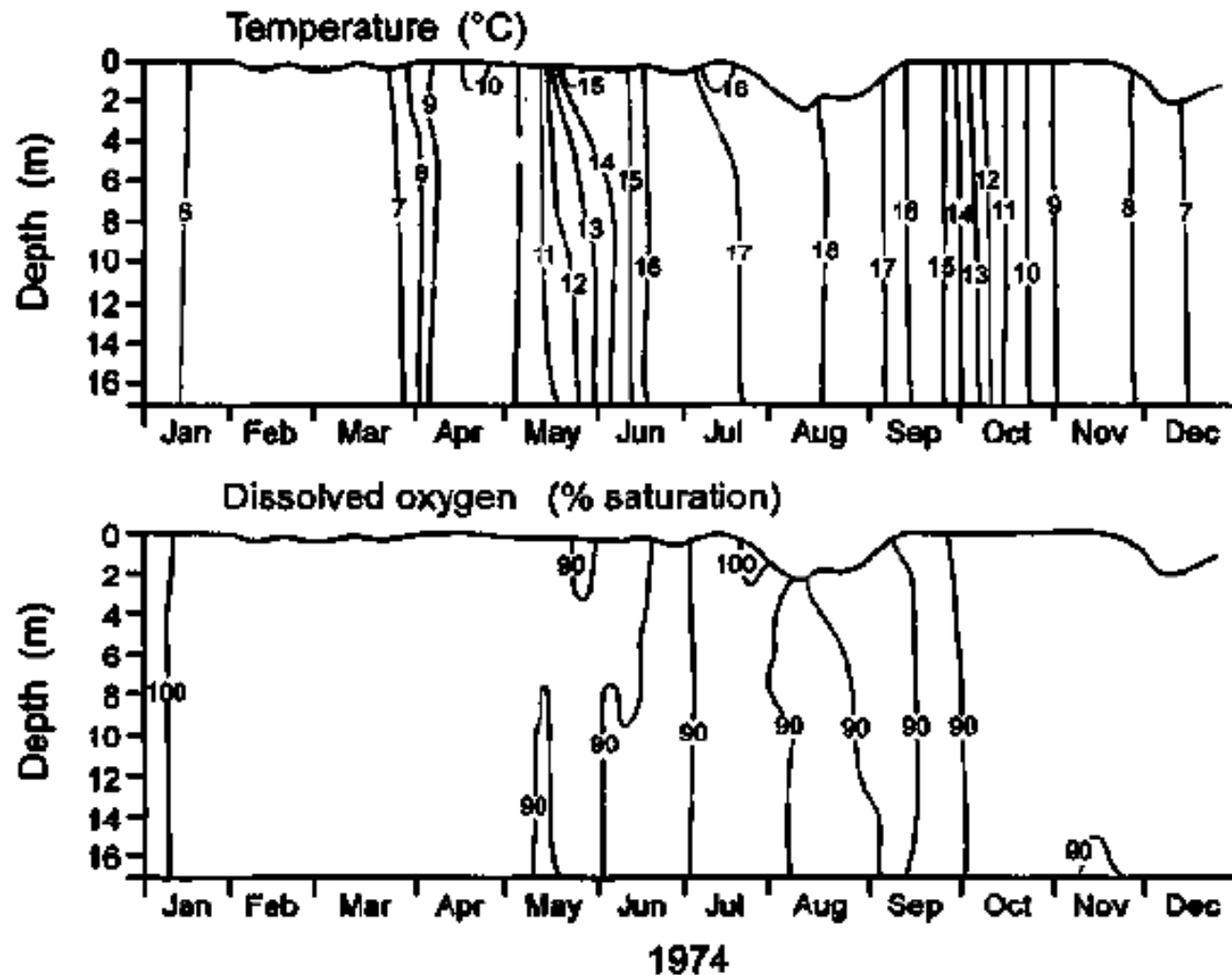
Noticia http://historico.elpais.com.uy/13/03/27/pciuda_705413.asp

Figure 8.18 Depths distributions of chlorophyll a and dissolved oxygen concentrations in relation to the water withdrawal points in the highly eutrophic King George VI reservoir, UK, during the summer months, prior to the application of any management regime (compare with the managed reservoir in Figure 8.12) (After Steel, 1972)



(Thornton et al 1996)

Figure 8.12 Uniformity in annual temperature and dissolved oxygen depth distributions in Queen Elizabeth II reservoir, UK achieved by jet-mixing in the water column. Compare with an unmanaged situation in a similar reservoir in Figure 8.18.



(Thornton et al 1996)

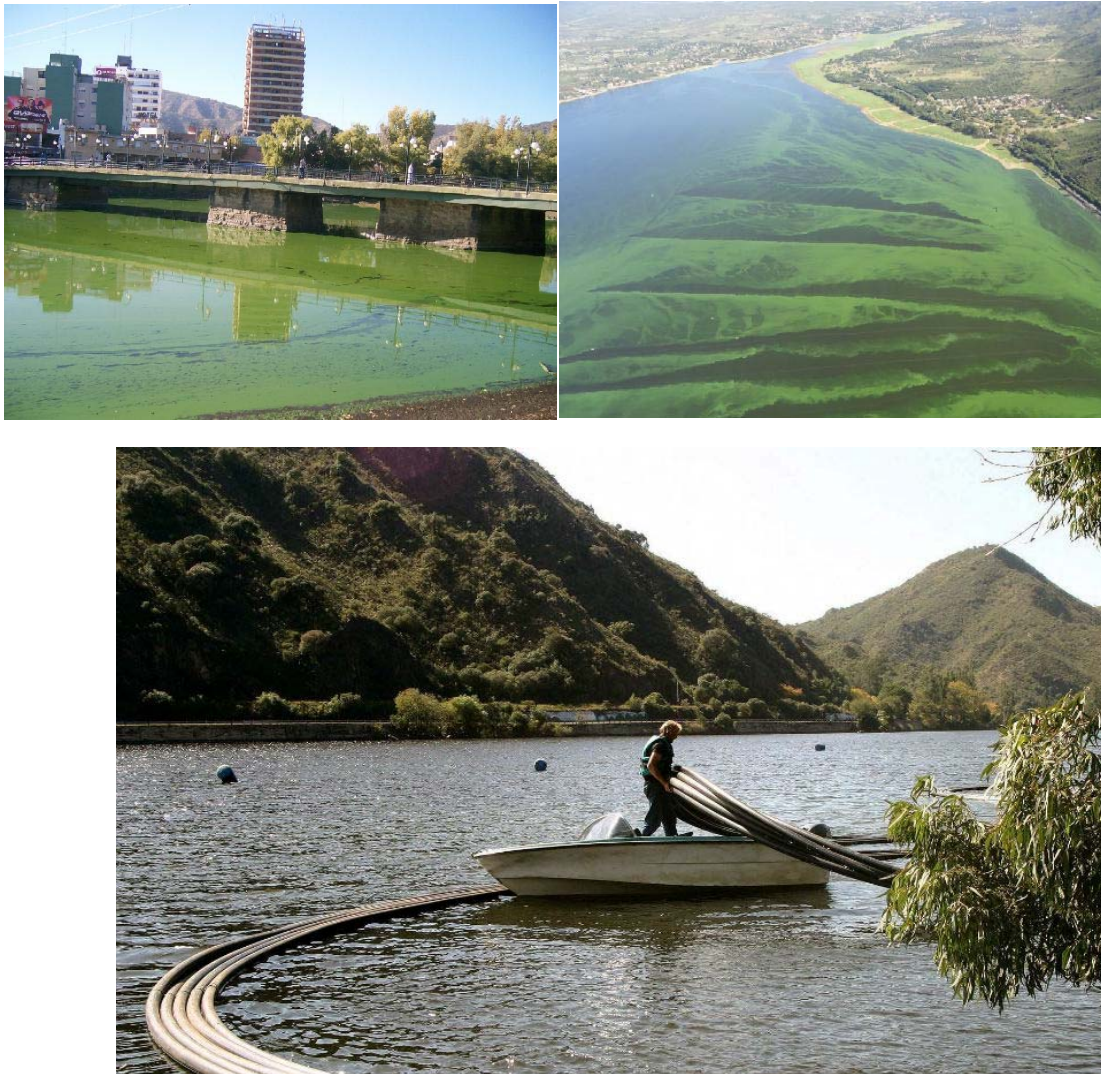


FIG. 40.- Embalse san roque (carlos paz, córdoba, argentina).

Arriba: estado ambiental, intensas floraciones.

<http://www.funeat.org.ar/art%c3%adculoscarlosproseri.html>.

Abajo: instalación de sistema de difusores

(<http://www.diaadia.com.ar/cordoba/san-roque-menos-verde-difusores>).

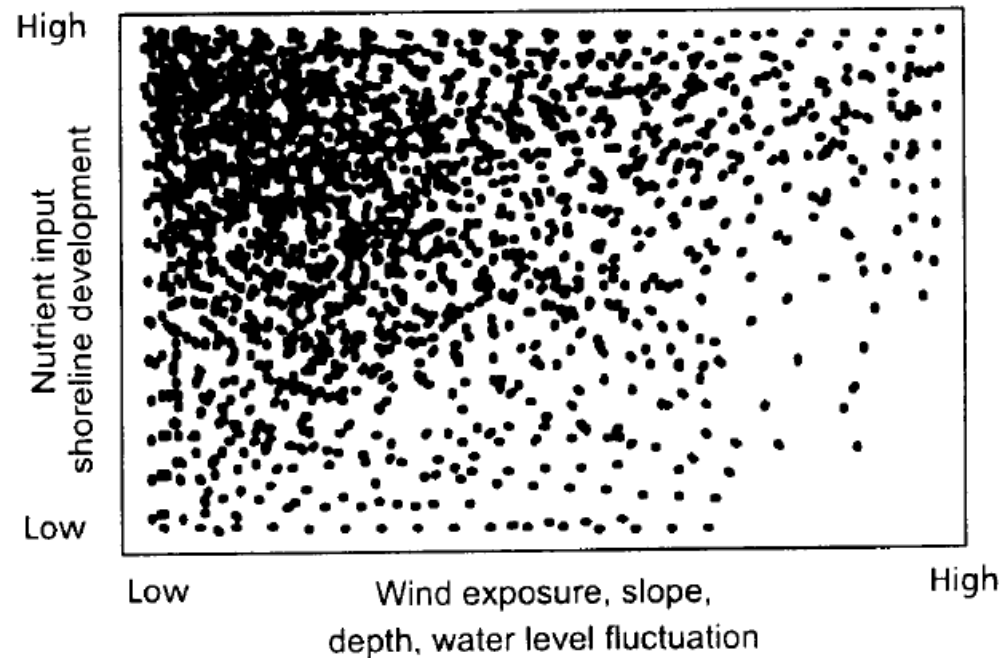
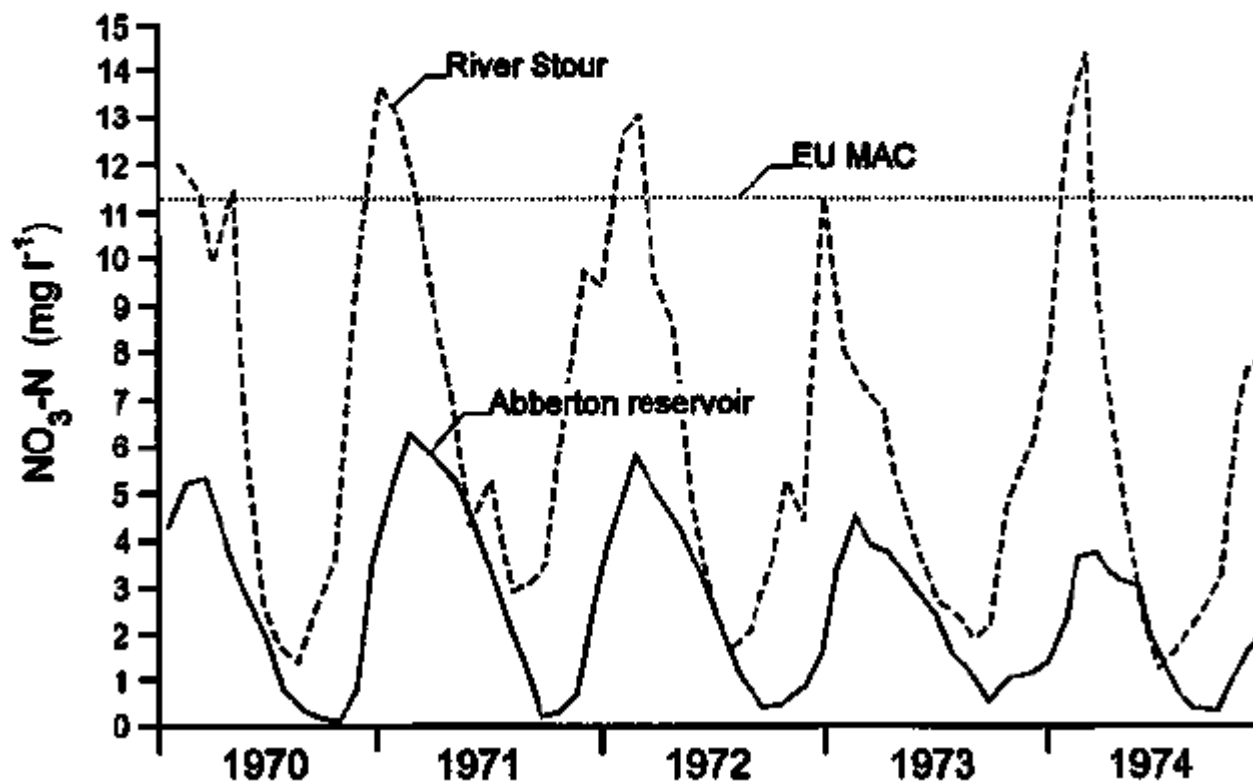


Figure 5 Hypothetical tendency of colonization of aquatic macrophytes in reservoirs. The degree of colonization is directly related with points density (after Thomaz and Bini, 1998b).

(Tundisi & Straskraba 1999)

Figure 8.17 Annual variation in the nitrate-nitrogen concentrations in the River Stour, UK compared with the concentrations in the waters of the Abberton reservoir which is supplied by the river. De-nitrification in the reservoir helps to reduce the nitrate-nitrogen concentrations to below guideline levels for drinking water. (After Slack, 1977)



(Thornton et al 1996)



[San Clemente Dam on the Carmel River after a heavy rainfall \(NOAA\)](#)

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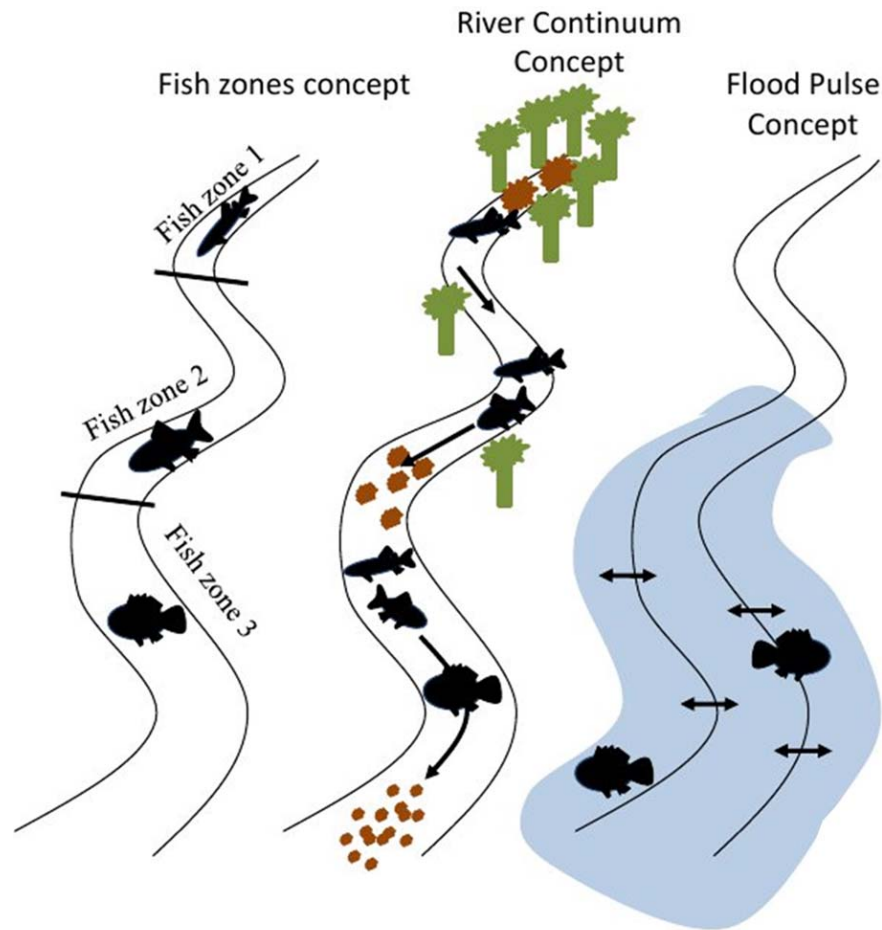
RESERVORIOS

Efectos “colaterales”:

Alteración del régimen hidrológico natural:

1. Inundaciones en regiones de aguas arriba
2. Inundan y crean nuevos hábitats
3. Aumentan el volumen de agua evaporada
4. Merma de los caudales circulantes aguas abajo
5. Modificación de las condiciones geomorfológicas del cauce (sedimentación)
6. Alteración de las zonas bajas que perturba el ciclo natural de peces y otros organismos acuáticos (alteración de corredores ecológicos naturales)
7. Alteración de los hábitats y los paisajes fluviales: fragmentación del hábitat
8. Desaparecen tierras cultivables, dificulta la navegación fluvial
9. Modifican la calidad del agua
10. Emiten gases de efecto invernadero
11. Desplazamiento de comunidades enteras
12. Cambios forzados en las actividades de subsistencia

Presas y funcionamiento de ecosistemas lóticos



Discontinuidad seriada

De acuerdo a la hipótesis del continuo las comunidades se organizan espacialmente de acuerdo a la variación de las propiedades físicas y químicas del sistema, en consecuencia las diferentes comunidades también presentan un continuo en algunos de sus atributos o propiedades; la construcción de una represa crea una discontinuidad.

Ej.
P/R ratio ?
Heterogeneidad ambiental?

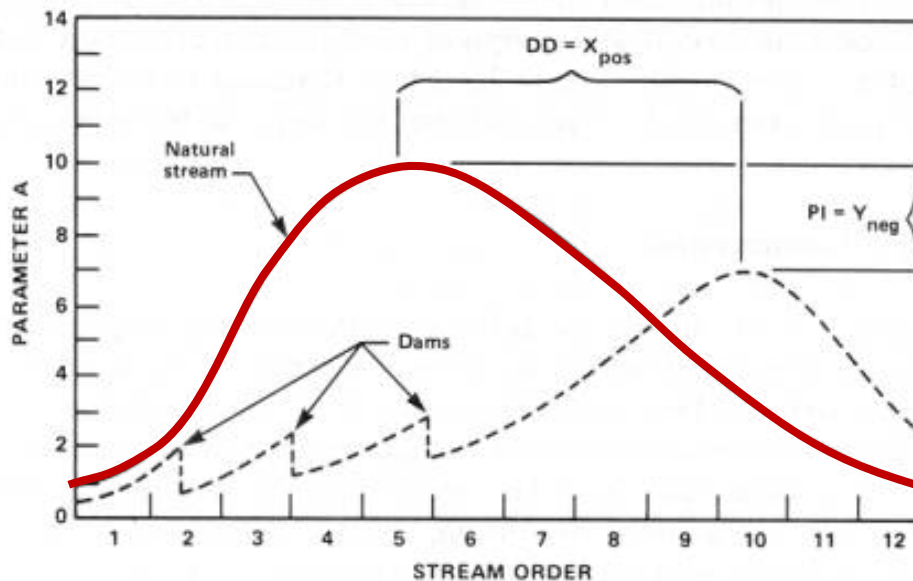


Figure 3. Theoretical framework for conceptualizing the influence of impoundment on ecological parameters in a river system. Discontinuity distance (DD) is the downstream (positive) or upstream (negative) shift of a parameter a given distance (X) due to stream regulation. PI is a measure of the difference in the parameter intensity attributed to stream regulation.

Discontinuidad seriada

Estas condiciones alteradas por la construcción de una presa son reestablecidas aguas abajo, estas generalmente se identifican y se cuantifican en términos de la distancia en que existe una recuperación de las características estudiadas.

Ej.
P/R ratio
Heterogeneidad ambiental

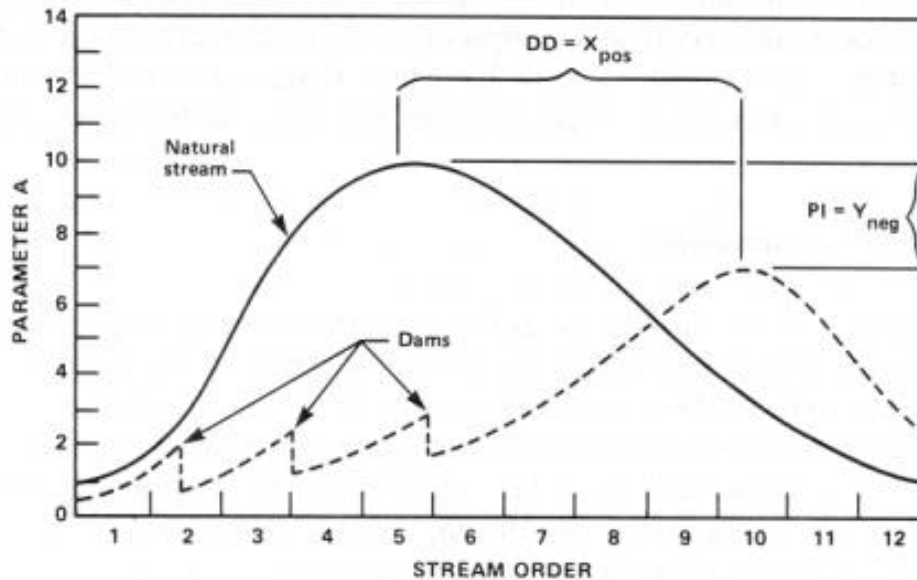
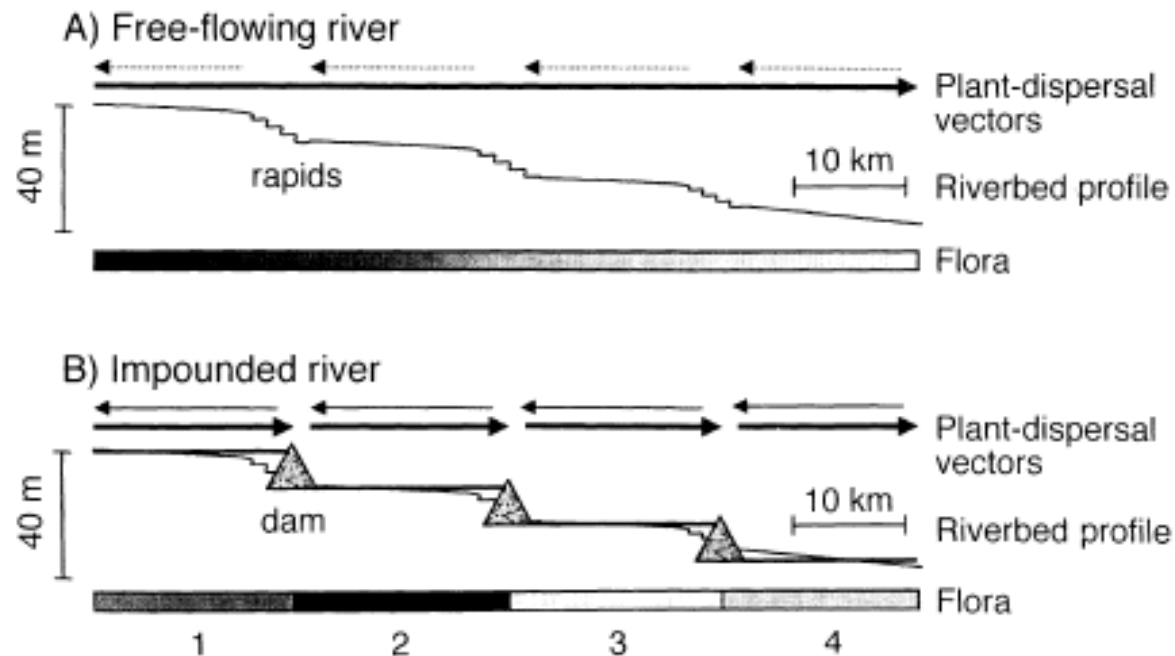


Figure 3. Theoretical framework for conceptualizing the influence of impoundment on ecological parameters in a river system. Discontinuity distance (DD) is the downstream (positive) or upstream (negative) shift of a parameter a given distance (X) due to stream regulation. PI is a measure of the difference in the parameter intensity attributed to stream regulation.

Discontinuidad seriada



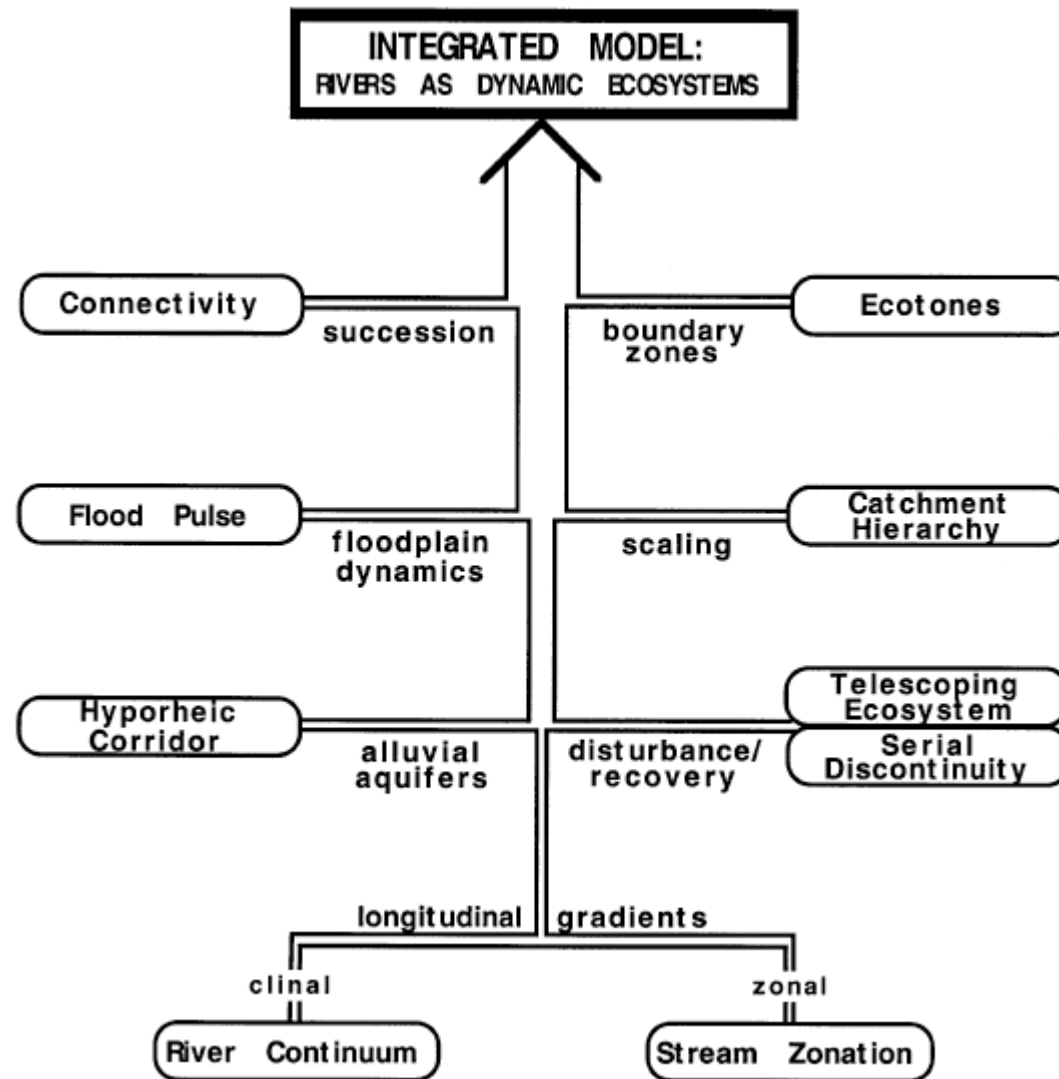
cascaded reservoirs

Figure 1-2. Hypothesized relationships between plant-dispersal vectors, riverbed profile, and composition of the riparian flora in free-flowing versus impounded rivers. (A) The flora in the free-flowing river is hypothesized to describe a gradual change downstream, whereas (B) in the regulated river, each impoundment is projected to develop an individual flora (denoted 1–4). (From Jansson et al., 2000a, copyright © Ecological Society of America; reprinted by permission.)



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Ward et al 2002

GRANDES REPRESAS Y COMUNIDAD DE PECES

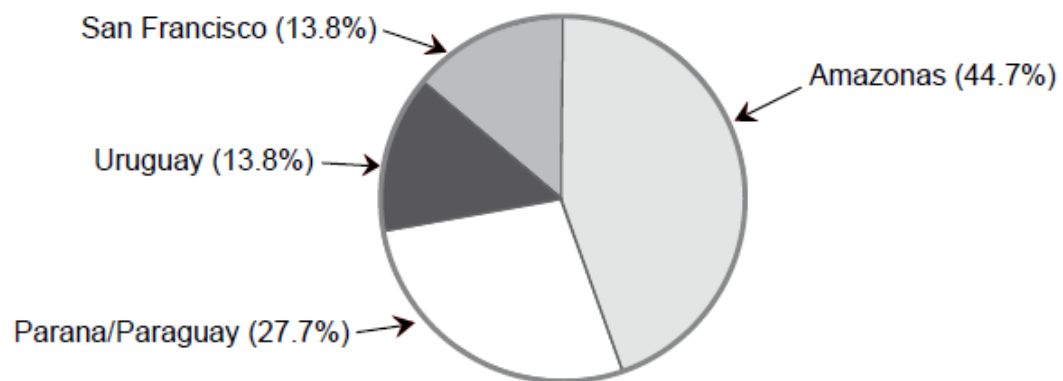


Figura 16.4. Porcentaje de especies migradoras por cuenca (adaptado de Agostinho *et al.*, 2007a)

<http://www.faunagua.org/biblioteca/3Cap16.pdf>

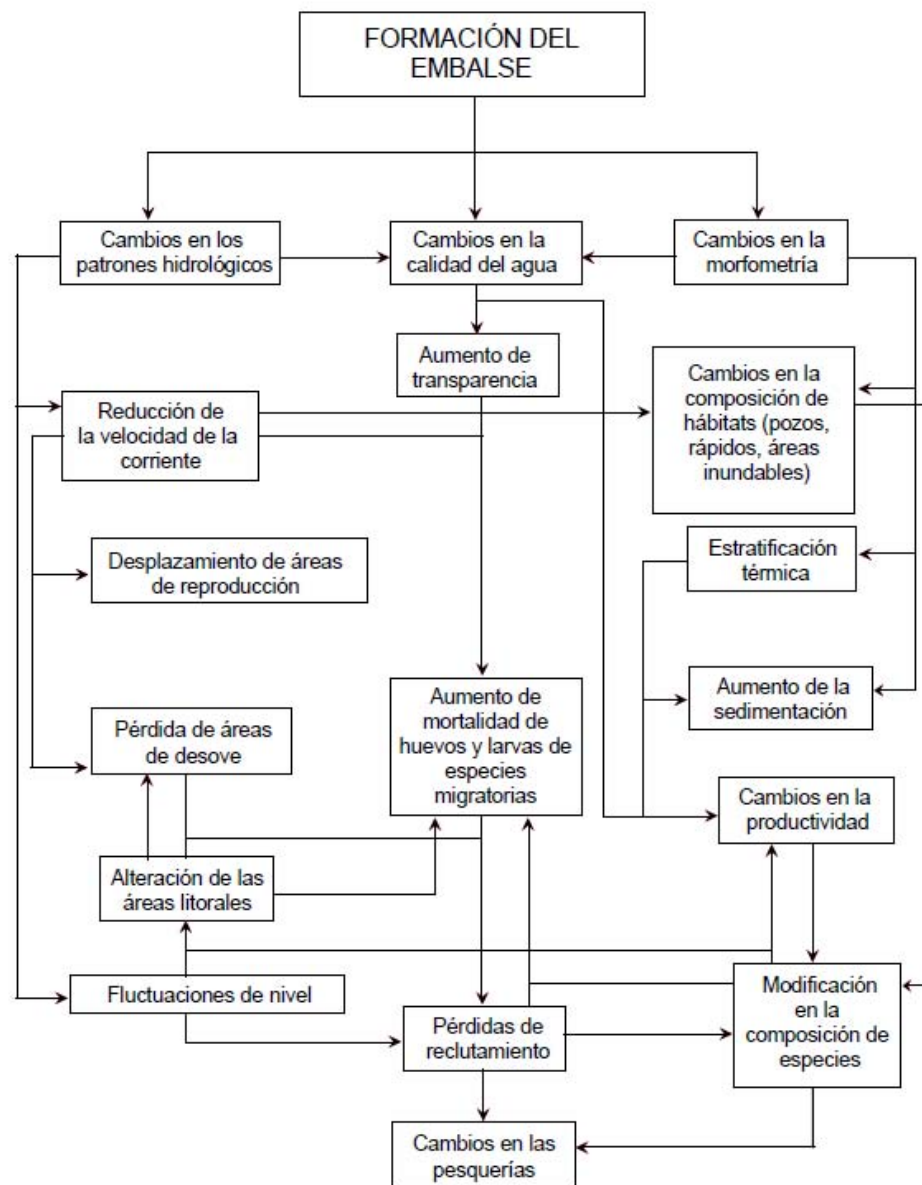


Figura 16.2. Potenciales impactos generados sobre las comunidades de peces aguas arriba de una represa, a partir de cambios en factores ambientales relevantes que ocurren por la construcción de un embalse (Elaboración propia)

<http://www.faunagua.org/biblioteca/3Cap16.pdf>

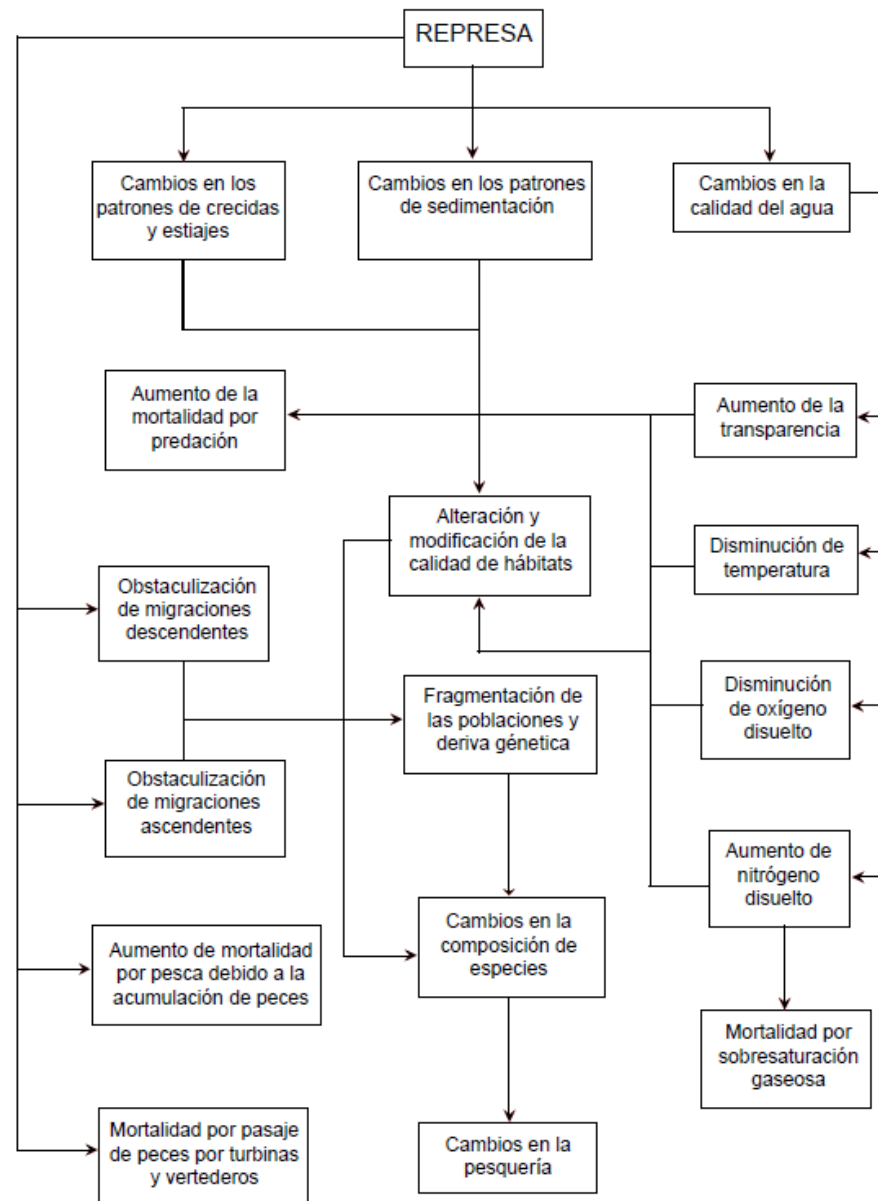


Figura 16.3. Potenciales impactos generados sobre las comunidades de peces aguas abajo de una represa, a partir de cambios en factores ambientales relevantes que ocurren por la construcción de un embalse (Elaboración propia)

<http://www.faunagua.org/biblioteca/3Cap16.pdf>

Cuadro 16.3. Comparación de diferentes sistemas de traspaso utilizados en ríos sudamericanos (adaptado de Oldani *et al.*, 2007).

Sistema	Ventajas	Desventajas	Ejemplos
Ranuras verticales ("vertical slots")	Permite operar con diferentes niveles de agua.	Ofrece dificultades de paso para especies de gran porte. Carece de áreas de descanso para los peces.	Represa de Igarapava (río Grande, Brasil)
Escaleras (escalones-tanques) ("pool and weir")	Apropiadas para represas de baja altura y gran flexibilidad de diseños.	Alta selectividad de especies. Sensible a los cambios de caudal. Poca efectividad para especies de fondo.	Represa de Lajeado (río Tocantins, Brasil) Represa de Salta Morais (río Tijuco, cuenca alta del río Paraná, Brasil)
Ascensores	El costo es independiente de la altura de la represa. Requiere poco espacio para su instalación. Poco sensible a las variaciones de nivel del embalse.	Costo elevado de construcción, operación y manutención. Genera estrés en los peces y mortandad por aglomeración. El número de peces transferidos depende del volumen del ascensor y del tiempo del ciclo.	Represa Engenheiro, Represa Sergio Motta (río Paraná, Brasil) Represa de Funil (río Grande, Brasil) Yacyreta (río Paraná, Argentina-Paraguay) Represa Santa Clara (río Mucuri).
Esclusas ("fish locks")	Diseño flexible que puede ser adaptado a distintos tipos de represas hidroeléctricas.	Baja capacidad de transferencia. El número de peces transferido depende del número de ciclos diarios. Durante la fase del llenado, el flujo de atracción se reduce o se elimina.	Represa de Salto Grande (río Uruguay, Argentina-Uruguay)
Sistemas de by-pass (ríos artificiales)	Alta capacidad de transferencia. Permiten simular las condiciones naturales del río. Amplio espectro de velocidades de agua. Utilizables para migraciones descendentes. Proporcionan hábitats para especies residentes.	Requieren de un amplio espacio para su instalación cuando la altura de la represa es considerable debido a su baja pendiente. Susceptible a variaciones del nivel de agua en el reservorio. Riesgo de introducción de especies no-deseadas.	Canal de Piracema, Represa Itaipú, río Paraná (Paraguay-Brasil)

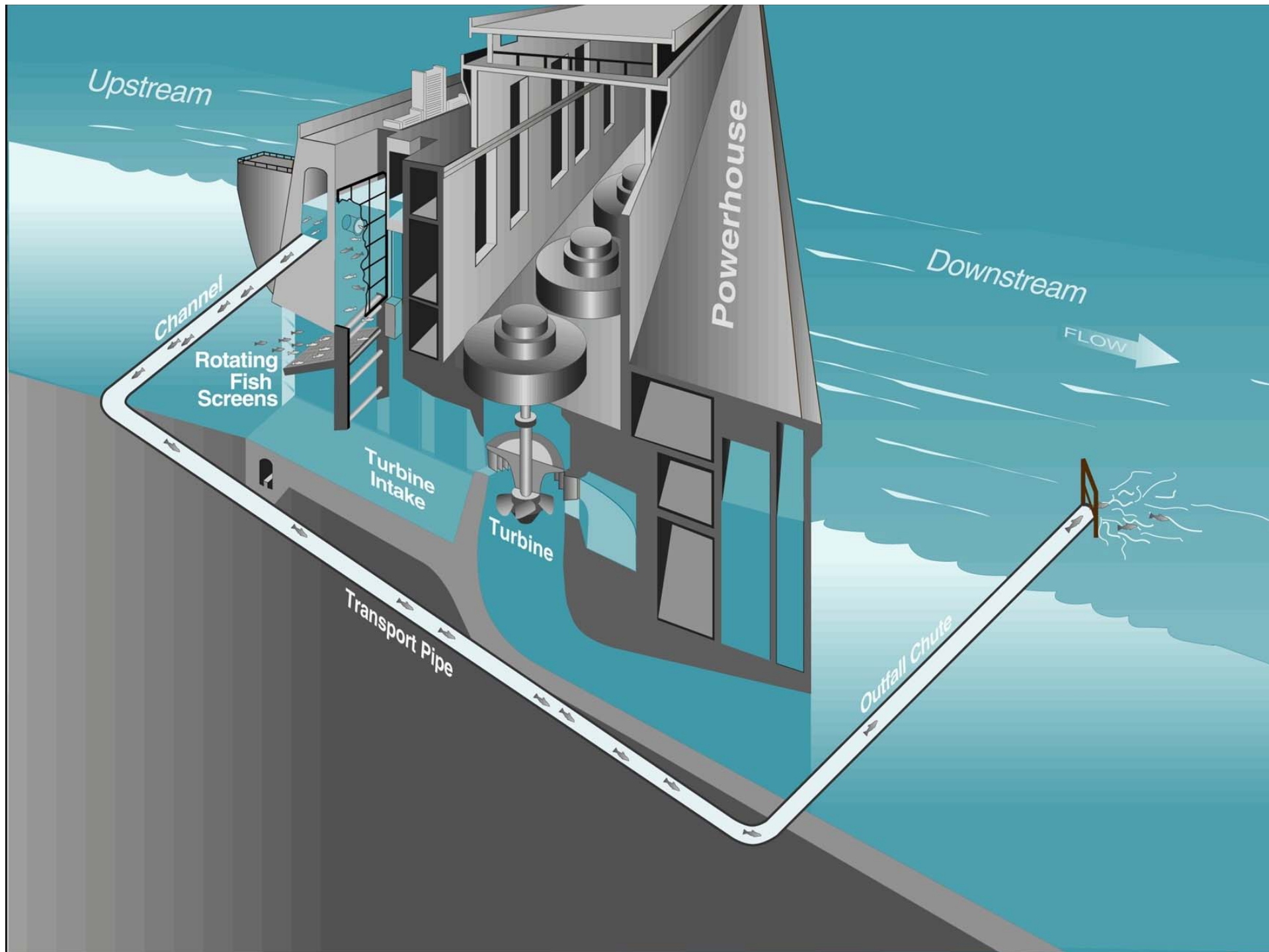




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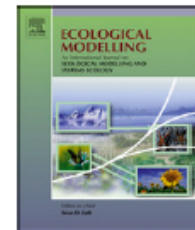




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Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel



Adapting the operation of two cascaded reservoirs for ecological flow requirement of a de-watered river channel due to diversion-type hydropower stations

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Undamming Rivers: A Review of the Ecological Impacts of Dam Removal

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ABSTRACT. Dam removal continues to garner attention as a potential river restoration tool. The increasing possibility of dam removal through the FERC relicensing process, as well as through federal and state agency actions, makes a critical examination of the ecological benefits and costs essential. This paper reviews the possible ecological impacts of dam removal using various case studies.

Restoration of an unregulated flow regime has resulted in increased biotic diversity through the enhancement of preferred spawning grounds or other habitat. By returning riverine con-

ditions and sediment transport to formerly impounded areas, riffle/pool sequences, gravel, and cobble have reappeared, along with increases in biotic diversity. Fish passage has been another benefit of dam removal. However, the disappearance of the reservoir may also affect certain publicly desirable fisheries.

Short-term ecological impacts of dam removal include an increased sediment load that may cause suffocation and abrasion to various biota and habitats. However, several recorded dam removals have suggested that the increased sediment load caused by removal should be a short-term effect. Pre-removal studies for contaminated sediment may be effective at controlling toxic release problems.

Although monitoring and dam removal studies are limited, a continued examination of the possible ecological impacts is important for quantifying the resistance and resilience of aquatic ecosystems. Dam removal, although controversial, is an important alternative for river restoration.

Dams are pervasive features of the world's river systems. There are more than 75,000 dams above 5 ft tall in the United States and 40,000 dams over 50 ft tall worldwide (National Research Council 1992, Dynesius and Nilsson 1994, McCully 1997). Smaller dams (i.e., below 5 ft tall) in the United States likely number in the thousands (American Rivers and NPS 1996). Nearly 80% of the total discharge of large rivers in the northern third of the world is impacted by river regulation (Dynesius and Nilsson 1994). This large number of dams worldwide can be attributed to the variety of services they provide: inexpensive and efficient power generation, effective flood control, navigation, water supply, irrigation, and recreational opportunities.

Nevertheless, the presence of dams is problematic for many aquatic ecosystems. Dams impact ecosystems in a number of ways: altering the natural cycle of flow, transforming the biological and physical characteristics of river channels and floodplains, and fragmenting the continuity of rivers (Petts 1984, Ghiselin 1994, Yeager 1994, Ligon and others 1995, Ward and Stanford 1995, Stanford and others 1996, Poff and others 1997). Lat-

eral exchanges of sediment, nutrients, and organisms between aquatic and terrestrial areas may be limited by fewer overbank floods in a dammed river (Junk and others 1989, Naiman and others 1993). Coastal areas may lose valuable habitat and shift biotic composition when they are deprived of sediment because of dammed rivers upstream (DOI 1996). The physical obstruction of both dams and reservoirs impedes and delays the migration of various organisms (Drinkwater and Frank 1994, Staggs and others 1995, Stanford and others 1996). The turbines of a hydropower operation harm fish and other biota as they attempt to pass (Dadswell 1996). The change from a river to a reservoir ecosystem often shifts species composition. Unnatural timing of flow releases for power production and the altered temperatures of those releases can confound emergence or growth cues (Petts 1984).

Recognition of these impacts has led to a search for solutions. For example, in the United States, the Federal Energy Regulatory Commission (FERC) relicensing process for hydropower operations is critically examining the environmental impacts of dams (American Rivers and NPS 1996). FERC issues 30- to 50-year licenses to dams owned by nonfederal entities, such as utility companies, municipalities, and independent

KEY WORDS: Dam removal; Restoration; Mitigation; Flow regime; Sediment; Fish passage

Environmental Management Vol. 27, No. 6, pp. 803-814

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RESERVORIOS

Bibliografía recomendada

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