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BIBLIOGRAPHIE ANNOTEE :

EVALUATION DE L'EFFICACITE DES TRAVAUX DE RESTAURATION DES HABITATS PHYSIQUES DES COURS D'EAU

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FDP74. 2008/01

FEVRIER 2008

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EVALUATION DE L'EFFICACITE DES TRAVAUX DE RESTAURATION DES HABITATS PHYSIQUES DES COURS D'EAU

REFERENCE A CITER : Vigier L. & Caudron A., 2008. Bibliographie annotée : évaluation de l'éfficacité des travaux de restauration des habitats physiques des cours d'eau. FDP74. 2008/01, 137p.

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Sommaire

Préface

Cette revue bibliographique a pour objectif de fournir une vision de l'état actuel des connaissances en ce qui concerne l'évaluation des travaux de restauration de l'habitat physique des cours d'eau.

Cette synthèse s'adresse à toutes les structures en charge de la gestion des milieux souhaitant réaliser l'évaluation des travaux de restauration de l'habitat qu'ils entreprennent. A travers les 282 références citées, sont abordés :

- l'origine historique des aménagements de l'habitat à base de structure,
- l'efficacité à court et long terme de ces aménagements à partir de nombreux exemples et synthèses d'exemples,
- les descripteurs et méthodes d'évaluation,
- les évolutions dans les pratiques de restauration et les perspectives d'évolution de cette discipline scientifique relativement récente.

Ce travail s'interresse uniquement à la problématique de l'évaluation de l'efficacité des actions de restauration réalisées et ne constitu donc pas un support technique à la conception des projets.

En outre, les problématiques telles que : la modifications des débits, la gestion des eaux d'orage, la connectivité longitudinale (franchissement piscicole et transport sédimentaire), la gestion de la ripisylve, la reconnection des plaines alluviales… ne sont pour la plupart qu'abordées, à travers certaines références. Cependant, leurs effets plus ou moins directs dans la gestion et la restauration physique des milieux sont évidents, mais ils ont été volontairement écartés de cette synthèse.

La recherche de la bibliographie a été réalisée par le biais de moteur de recherche scientifique et de sites spécialisés (cités dans la rubriques ressources informatique). Nous avons ainsi pu rassembler 282 références, appartenant pour la grande majorité à la littérature scientifique.

En complément, une liste des travaux français et francophones (européens) disponibles sur le sujet (retour d'expériences, manuels, techniques…) a été dressé. Cette recherche, a été réalisé par l'intermédiaire d'internet et par la sollicitation directe des personnes concernées par des projets portés à notre connaissance. Ainsi cette liste est loin d'être exhaustive si l'on considère le nombre de documents vraissemblablement existants, mais elle met en évidence, par le peu de documents qu'elle présente, le manque de partage des expériences.

Enfin, afin de porter à connaissance ce travail en cours pendant l'année 2007, 2 présentations ont été réalisées dans le cadre des colloques de St-Malo (Journées Nationales d'Echanges Techniques milieux aquatiques et pêche) et de Namur-Belgique (La gestion physique des cours d'eau, Bilan d'une décennie d'ingénierie écologique). A travers notre participation à ces colloques nous avons pu nous rendre compte des diverses expériences d'évaluation réalisées ou en cours, nouer des contacts et porter à connaissance ces diverses expériences à travers notre travail.

La présente synthèse a été réalisée sur la base de l'analyse de 242 articles parus dans des revues scientifiques entre 1949 et 2007 et traitant de l'évaluation des travaux de restauration de l'habitat physique des cours d'eau.

L'augmentation récente et exponentielle, depuis le début des années 90, des travaux scientifiques dans ce domaine (figure1), traduit à une moindre échelle l'engouement mondial des gestionnaires des milieux aquatiques vis-à-vis de ce type d'aménagement (Nakamura *et al.*, 2006). Actuellement, la restauration des milieux aquatiques constitue une « industrie multimilliardaire » à travers le monde entier (Brooks & Lake, 2007). Aux Etats-Unis, les dépenses effectuées pour la restauration de l'habitat physique des cours d'eau sont estimées à plus d'un milliard de dollars par an (Bernhardt *et al.*, 2007 ; Roni *et al.*, 2002 ;). Au Japon, près de 25.000 projets de restauration ont été initié entre 1990 et 2004 (Nakamura *et al.*, 2006).

En ce concerne la production de documents, nous observons une grande disparité géographique (figure 1). En effet, l'Amérique du Nord (Etats-Unis et Canada) domine largement la discipline. Ils sont les premiers à s'être intéressé à cette problématique et sont à l'origine de 60% de l'ensemble des articles recueillis. Viennent ensuite, les pays d'Europe du Nord (UK, Irlande, Finlande, Norvège, Danemark, Suède) et de l'Est (Allemagne, Autriche,…) qui se sont intéressés à ce sujet à partir de la fin des années 80 et qui maintiennent depuis un effort constant dans la recherche. Depuis le début du 21ème siècle, nous observons l'essor de l'Australie, de la Nouvelle-Zélande (Océanie) et du Japon (Asie) dans ce domaine ainsi que l'apparition de plus en plus de publications rassemblant divers spécialistes internationaux. Enfin, nous remarquons la quasi-absence de documents d'origine française, d'Europe du sud et des pays francophones d'Europe, qui représentent moins de 3% des articles récoltés.

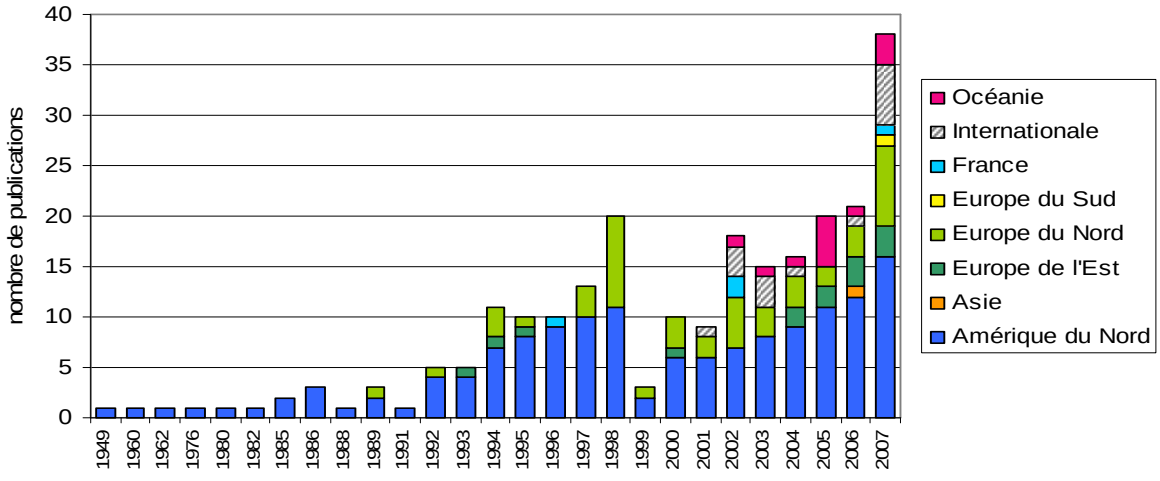

Figure 1 : Evolution temporelle de l'origine géographique des 242 publications issues de revues scientifiques et traitant de l'évaluation de travaux de restauration de l'habitat physique des cours d'eau.

Cette évolution géographique est à mettre en parallèle avec les changements d'objectifs et de motivations à l'origine de la réalisation de tels travaux.

Les Etats-Unis ont été les premiers à réaliser des travaux de « restauration active » de l'habitat physique à des fins halieutiques dès la fins des années 1880. Dans l'objectif

d'améliorer localement les conditions de pêche ou de tenter de rétablir les populations de salmonidés touchées par une pêche excessive, les structures rigides type déflecteurs, seuils, sous berges… ont alors fait leur apparition (Thompson, 2005 ; Thompson & Stull, 2002).

Le cadre d'utilisation de ces techniques a évolué dès le début des années 80 dans le sens de la réhabilitation des cours d'eau dégradés souffrant de problèmes d'homogénéisation de l'habitat (chenalisation, rectification)… Les causes de ces dégradations physiques sont diverses (O'Donnel & Galat, 2007) : drainage liés à l'intensification de l'agriculture (Harrison *et al.*, 2004 ; Hvidsten & Johnsen, 1992 ; Pedersen *et al.*, 2007a), utilisation des rivières pour le flottage du bois principalement en Europe du Nord (Huuskö & Yrjäna, 1995 ; Laasonen *et al.*, 1998, Lepori *et al*., 2005 ; Linlokken, 1997 ; Muotka *et al.*, 2002), extraction de granulat (Habersack & Piégay, 2007), extension des zones urbaines (Walsh *et al.*, 2005 ; Larned *et al.*, 2006 ; Brooks *et al.*, 2002)…

Ainsi, durant les 25 dernières années, la gestion des rivières évolue vers des pratiques de restauration de l'intégrité écologique des milieux qui devient un objectif majeur (Rohde *et al.*, 2004) au niveau mondial; et plus particulièrement, au point de vue européen, dans le cadre de la Directive Cadre Européenne (England *et al.*, 2007). Dans ce contexte, la restauration de l'habitat physique a émergée comme une activité clé pour les gestionnaires chargés de « réparer » les dégâts induits par les activités anthropiques (Bond & Lake, 2003 ; Kauffman *et al.*, 1997 ; Brooks *et al.*, 2002). L'augmentation exponentielle du nombre de projets et donc des sommes investies dans le domaine de la restauration a entraîné un besoin quant à l'amélioration des pratiques de restauration dans un objectif d'optimisation technique et financière des futures projets (Minns *et al.*, 1996 ; Moerke *et al.*, 2004 ; England *et al.*, 2007 ; Kondolf, 1995 ; Kondolf *et al.*, 2005 ; Purcel *et al.*, 2002). De ce constat émerge la nécessité de tirer les enseignements de toute les expériences de restauration par le biais de l'évaluation et du suivi de ces travaux et de les partager (Minns *et al.*, 1996 ; Smokorowski *et al.*, 1998).

En outre, il existe un besoin de prouver l'efficacité de ces travaux dans l'objectif de justifier auprès de tous : financeurs, citoyens, élus… de l'utilité des sommes dépensées pour ces travaux (Woolsey *et al.*, 2007 ; Nakamura *et al.*, 2006).

L'évolution de l'évaluation des actions de restauration : naissance de la discipline scientifique et applications.

La majorité des articles scientifiques recueillis exposent l'évaluation d'un (ou de quelques) exemple(s) de restauration (figure 2).

Au milieu des années 90, la parution de nouveaux types d'articles (figure 2) traitant : des techniques de conception, des méthodologies d'évaluation de ce type de travaux, de la recherche de modèles prédictifs des actions de restauration, de la réalisation de synthèses de divers projets, des méthodologies de conception de stratégies de restauration… marque le début de la structuration de cette discipline. On trouve également de nombreux articles définissant les bases stratégiques d'une gestion intégrée à l'échelle du bassin, au sein de laquelle la restauration physique des habitats est selon les cas, la conséquence des actions effectuées à une plus grande échelle ou une action locale appartenant au plan de restauration défini à l'échelle du bassin. Plus récemment, depuis 2004, l'apparition de nombreuses synthèses de bases de données qui recensent les projets réalisés à une large échelle (pays), reflète les prémices d'un rapprochement entre la communauté scientifique et les gestionnaires des milieux.

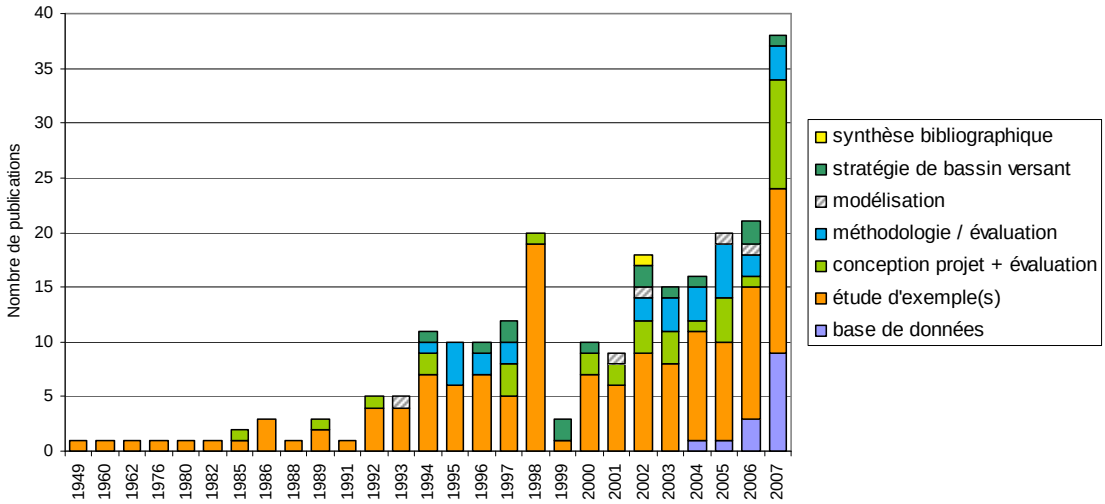

Figure 2 : Evolution temporelle des sujets des 242 publications issues de revues scientifiques et traitant de l'évaluation de travaux de restauration de l'habitat physique des cours d'eau.

Du point de vue des études de cas, on note que ces exemples évoluent au cours du temps de tentatives d'amélioration des caractéristiques à des petites échelles vers des projets plus ambitieux de restauration écologique à des échelles spatiales supérieures (Kauffman *et al.*, 1997). Ce changement de pratique semble lié au constat de nombreux échecs (Frissell & Nawa, Roni *et al.*, FAO, 2005 ; Kondolf, 1995). Certains auteurs (Moerke *et al.*, 2004) constatent en effet que la majorité des échecs concernant des travaux de restauration de cours d'eau réalisés à l'échelle de tronçon sont la conséquence de dégradations non traitées du bassin versant (Larson *et al.*, 2001) ou d'autres problèmes plus ponctuels non pris en compte dans la conception du projet (barrières limitant la recolonisations, présences d'espèces introduites….) (Bond & Lake, 2003). Des perturbations liées à la mise en place d'une « gestion de l'habitat à cible unique » ne considérant qu'une seule espèce, ont été révélées (Muotka *et al.*, 2002 ; Minns *et al.*, 1996). En outre, Frissell & Ralph (1998), Thompson (2005) alertent sur le caractère statique et stable des aménagements, dits de restauration, basés sur des structures rigides qui peuvent perturber le milieu à long terme en le privant d'évolution physique.

Ainsi, malgré les milliers d'expériences de « restauration » réalisées dans le monde entier, de nombreux auteurs s'accordent à dire qu'il existe finalement peu de preuves des bénéfices de ces aménagements sur l'écosystème (Moerke & Lamberti, 2003, 2004 ; Alexander & Allan, 2006 ; Frissell & Ralph 1998 ; Palmer *et al.*, 2005). D'autre part beaucoup constatent que peu de projets subissent une évaluation de leurs effets (Pretty *et al.*, 2003 ; Rumps *et al.*, 2007 ; Kondolf & Micheli, 1995 ; Kondolf 1998) et que parmi ces quelques cas, peu d'évaluations sont appropriées (Alexander & Allan, 2007 ; Bernhardt *et al.*, 2005 ; Carlson & Quinn, 2005 ; Harisson *et al.*, 2004). En outre, très peu de responsables de projets font la démarche de partager leurs résultats et les leçons qu'ils ont tirés de leurs réussites ou de leurs échecs (Kondolf, 1995 ; Kondolf & Micheli, 1995 ; Kail *et al.*, 2007 ; Jansson *et al.*, 2007).

En effet, malgré une volonté forte d'encadrer plus rigoureusement ce type de travaux, une large confusion sur l'efficacité de tels travaux et sur la nécessité d'en évaluer les effets semble subsister pour 3 raisons principales :

- Historiques, liées à leur condition d'émergence fin du 19ème début du 20ème siècle aux Etats-Unis. Malgré la connaissance de nombreux échecs et inconvénients de ce

type d'aménagements (destruction par les crues, réduction de la diversité spécifique, perturbation des populations d'invertébrés, impacts géomorphologiques…) dès les années 1930, une majorité d'évaluations non appropriées et à court terme (inférieure à 5 ans) de nombreux projets ont conclue au succès (accroissement des populations de poissons) des aménagements (Thompson, 2005). L'extension de leur utilisation à une grande échelle, soutenue par des aides gouvernementales durant de nombreuses années, sans évaluation plus approfondies, a contribué à véhiculer la fausse croyance selon laquelle leurs effets bénéfiques sur les poissons a été démontré (Thompson & Stull, 2002), et par extension que leurs effets bénéfiques sur l'ensemble des paramètres du milieu étaient également démontrés (Brooks *et al.*, 2002). Ceci pouvant conduire à l'idée qu'une action de restauration est par définition favorable au milieu (England *et al.*, 2007) et au compartiment biologique dans son ensemble (Bond & Lake, 2003) et ne nécessite donc pas plus d'évaluation qu'un jugement visuel.

- Le manque d'anticipation concernant :
  - **1-** la conception et la réalisation du projet : les mesures de restauration des écosystèmes sont souvent réalisées dans la précipitation et sans prise en considération des connaissances actuelles sur les écosystèmes considérés (Minns *et al.*, 1996 ; Lake *et al.*, 2007),
  - **2-** la définition des objectifs du projet avant sa réalisation (Woolsey *et al.*, 2007 ; Kondolf *et al.*, 2007),
  - **3-** le financement des suivis qui n'est la plupart du temps pas inclue dans le projet (Cooperman *et al.*, 2007) car ils ne sont souvent pas considérés comme une part intégrante des projets (Frissell & Ralph, 1998).
- Le manque de clarté concernant la notion de succès des travaux de restauration ainsi que de guides méthodologique pour l'évaluer (Woosley *et al.*, 2007 ; Palmer *et al.*, 200 ; Zedler, 2007).

Sur la base de ces constats, des travaux récents basés sur des bases de données rassemblant plusieurs milliers de projets de restauration, ont eu pour sujet d'analyser les tendances globales en ce qui concerne les objectifs, les méthodes de restauration, la présence d'évaluation, la distribution spatiale, la taille et le coût des projets de restauration, la perception des succès et échecs et évaluer l'efficacité des actions réalisées (Alexander & Allan, 2006 ; Bernhardt *et al.*, 2005, 2007 ; Brooks & Lake, 2007 ; Moerke & Lamberti, 2002 ; Wheaton *et al.*, 2006 ; Follstad *et al*., 2007 ; Katz *et al.*, 2007 ; Kondolf *et al.*, 2007 ; O'Donnel & Galat, 2007 ; Palmer *et al.*, 2007 ; Rumps *et al.*, 2007 ; Sudduth *et al.*, 2007 ; Brooks & Lake, 2007 ; Bash & Ryan, 2002 ; O'Donnel & Galat, 2008). Ces bases de données ont pour but de documenter le plus fidèlement possible les tendances générales concernant l'utilisation des sommes d'argents et les efforts réalisés par les gestionnaires dans le domaine de la restauration des milieux aux échelles nationales et supranationales et permettre de faire ressortir les éléments de réussite des projets.

Les tendances mises en évidence sont les suivantes :

- le pourcentage de projets suivis est très variable selon les pays. Par exemple, aux Etats-Unis, le taux de suivi varie, selon les états et s'élève en moyenne à 10% à l'échelle nationale (USA) ; il se situe autour de 14 % en Australie,….
- les suivis sont pour la majorité mis en place volontairement à l'initiative des maîtres d'ouvrage du projet,
- les données collectées sont très différentes d'un projet à l'autre car elles sont très dépendantes des objectifs du projet, des moyens humains et financiers ainsi que de la disponibilité en temps….

- les projets les plus chers (de l'ordre de 400.000 $) sont le plus fréquemment évalués.
- la majorité des évaluations ou suivis mis en place ne sont pas considérés comme efficaces pour évaluer les conséquences des activités de restauration,
- les résultats et les enseignements issus des projets ne sont presque jamais diffusés.

Les implications pratiques de l'ensemble de ces constats sont que l'amélioration des connaissances et des pratiques de restauration des cours d'eau doit passer par une phase de systématisation de l'évaluation des projets de restauration accompagnée d'une harmonisation des méthodes et des indicateurs de suivis et donc des critères de succès et d'une large diffusion des enseignements issus de ces expériences.

Dans l'objectif de généraliser les évaluations de projet, les auteurs cités plus haut suggèrent une plus forte implication des organismes décideurs et financeurs auprès desquels ils sollicitent à la fois la mise à disposition de moyens supplémentaires associé à un cadre méthodologique. Ces mesures semblent d'autant plus nécessaires que la réalisation et la publication de nouvelles études scientifiques ne permettront vraisemblablement pas à elles seules une amélioration significative des pratiques de restauration. **Par contre une meilleure collaboration entre les scientifiques, les gestionnaires et les maîtres d'œuvre parait nécessaire à la progression de la science et de la pratique de la restauration de rivière.**

Quels outils pour évaluer le succès de travaux de restauration physique des habitats aquatiques ?

- Quelles méthodes d'évaluation ?

Le schéma de suivi et d'évaluation énoncé par Bernhardt *et al.* (2007), ou encore Kondolf (1995) consiste en 3 points :

1 – avoir des objectifs clairement définis et quantifiés,

2 – définir des critères de succès objectifs,

3 – mettre en place un suivi approprié avant et après (sur une durée suffisante) la réalisation du projet à la fois sur le site traité et sur un site de référence (contrôle) aussi appelé BACI (before-after-control-intervention) (Muotka & Laasonen, 2002 ; Harris *et al.*, 2005)

Cette méthodologie, largement utilisée dans les divers exemples étudiés dans le cadre de cette synthèse, a été largement éprouvée (Ex : Brooks *et al.*, 2004 ; Van Zyll de Jong *et al.*, 1998 ; Suren *et al.*, 2005 ; Lehane *et al.*, 2002 ; Moerke & Lamberti., 2003 ; Thomson *et al.*, 2005 ; Shields *et al.*, 2006 ; Moerke *et al.* 2004 ; Lake, 2005 ; Ryder & Miller, 2005, Rohde *et al.*, 2004, Chapman, 1995).

Le rôle des stations de contrôles est de fournir des repères comparatifs pour les différents indicateurs étudiés. Deux types de stations de contrôle sont fréquemment utilisés dans la littérature :

- une station de référence correspondant à la situation non dégradée proche de « l'état naturel »,
- une station correspondant au même état de dégradation physique, mais non restaurée.

En outre ces stations de contrôles permettent de prendre en compte les variabilités interannuelles naturelles (Ruiz-Jaen & Aide, 2005).

Concernant les choix des indicateurs, quelques références sont disponibles :

- Ruiz-Jaen & Aide, (2005) prônent l'utilisation de 2 variables par attributs de l'écosystème que sont : la diversité, la structure de la végétation et les processus

écologiques, et au moins 2 stations de références pour capter la variabilité de l'écosystème.

- Poole *et al.*, (1997) proposent également la mise en place de suivis s'appuyant sur des mesures directes, reproductibles, quantitatives, avec un bon rapport coût/efficacité et préconisent de sélectionner des indicateurs des compartiments et processus physiques, chimiques et biologiques recouvrant plusieurs échelles de résolution et ne pas s'appuyer uniquement sur une évaluation de l'évolution quantitative des unités d'habitat (% radier/mouille).

D'une manière générale, à partir de l'ensemble des exemples étudiés il ressort un besoin de baser l'évaluation d'un projet de restauration sur plusieurs indicateurs. Cependant, à l'heure actuelle, peu d'auteurs se sont employés à travailler véritablement sur la mise en place d'un cadre d'évaluation standardisé, alors que c'est bien là que la demande des gestionnaires se situe. Actuellement, à notre connaissance, seuls Woolsey *et al.* (2007), fournissent une trame standard appliquée basée sur 13 objectifs et 49 indicateurs.

- Quels indicateurs des changements physiques et biologiques des actions de restauration?

La synthèse des articles présentant des exemples d'évaluation de travaux de restauration de l'habitat physique des cours d'eau met en évidence (figure 3), en ce qui concerne le choix des indicateurs de suivi :

- que l'habitat (aspect géomorphologique compris) et l'état du compartiment piscicole sont presque systématiquement utilisés depuis les premières expériences d'évaluation au début du 20ème siècle,
- que l'étude des macroinvertébrés est devenue elle aussi très fréquente depuis la fin des années 1990,
- le faible nombre d'évaluations concernant la longévité des structures mises en place et leurs effets à long terme sur le milieu,
- l'apparition récente de descripteurs des fonctionnalités écologiques depuis le début des années 2000,
- l'utilisation plus sporadique d'autres types d'indicateurs dont l'intérêt de suivi est considéré au cas par cas (macrophytes, ripisylve, qualité de l'eau, autres…).

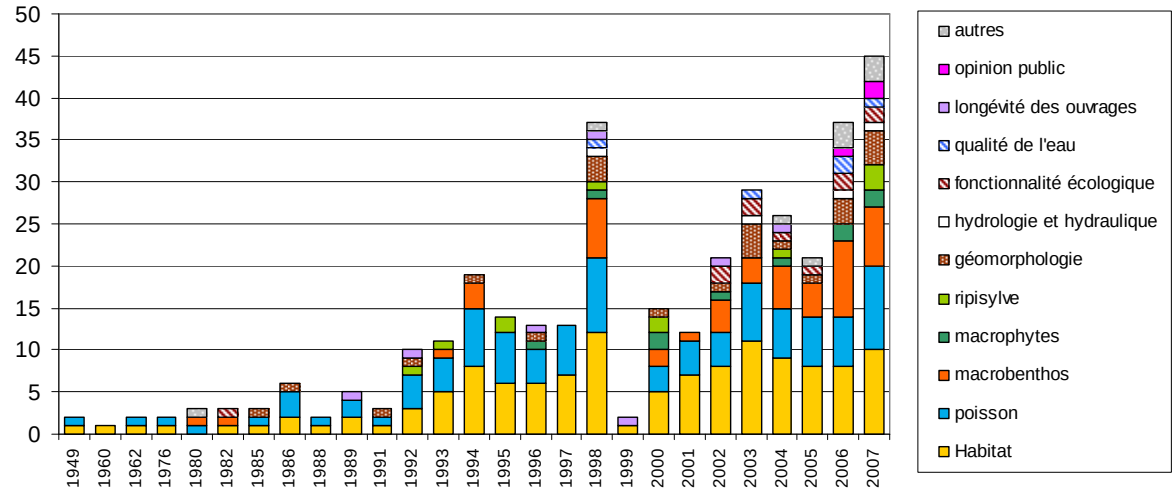

Figure 3 : Répartition des différents indicateurs utilisés entre 1949 et 2007 dans 168 publications issues de revues scientifiques, traitant de l'évaluation de travaux de restauration de l'habitat physique des cours d'eau.

En outre, le nombre moyen d'indicateurs suivi par projet a tendance à augmenter étant de plus en plus régulièrement supérieur à 4 (figure 4).

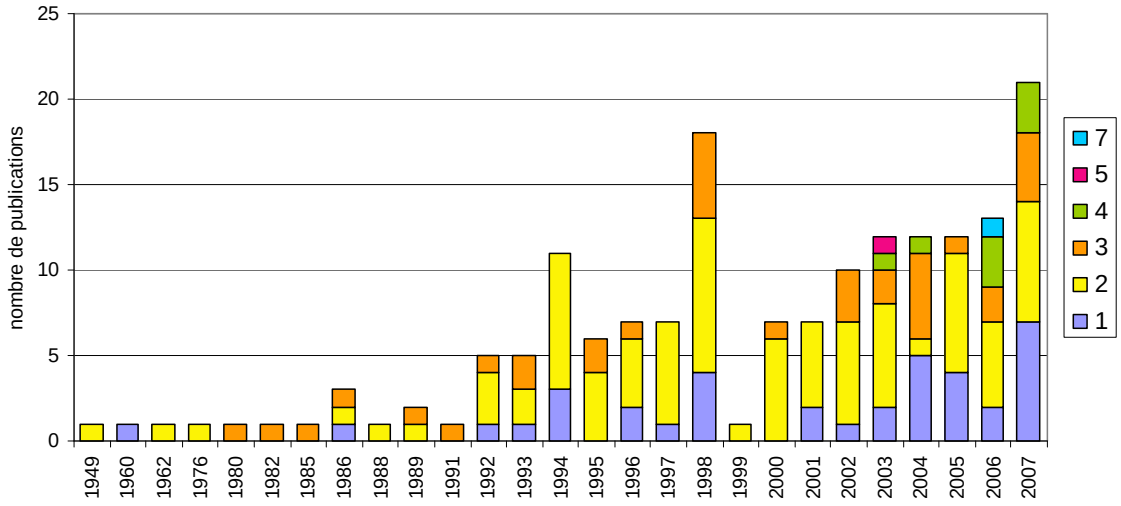

Figure 4 : évolution du nombre d'indicateurs utilisés entre 1949 et 2007 dans 168 publications issues de revues scientifiques et traitant de l'évaluation de travaux de restauration de l'habitat physique des cours d'eau.

Ces différentes constatations sont l'image du changement profond de la philosophie de la restauration de l'habitat physique des cours d'eau. D'aménagements à vocation palliative cherchant à influencer directement l'habitat pour répondre aux exigences d'une espèce piscicole ou de certains de ses stades de développement, on cherche désormais de plus en plus, à agir sur les causes de dégradation de l'habitat. Par conséquent, l'information recherchée à travers les divers indicateurs a changé de nature. **Ainsi, au simple constat quantifié de l'effet des aménagements sur les poissons par le biais de son habitat s'ajoute la mesure de paramètres permettant de juger de la réhabilitation des diverses fonctions de l'écosystème.**

- L'Evaluation de l'efficacité des travaux de restauration de types R1 et R2

La typologie des aménagements utilisée dans cette synthèse correspond à la typologie développée par BIOTEC Biologie appliquée et Malavoi (Rapport Agence de l'eau RMC, 2006). Elle considère 3 niveaux d'ambition de travaux de restauration en fonction de l'état du milieu. Dans notre cas nous ne considérons pas les deux premiers niveaux d'ambition que sont : la préservation (P) (cas de milieux en bon état de fonctionnement morpho-écologique) et la limitations des dysfonctionnements futurs (L) (cas d'un milieu dont le fonctionnement est légèrement dégradé). Nous nous concentrons sur l'évaluation des actions correspondant au niveau d'ambition restauration (R) (cas des milieux dégradés) et plus particulièrement aux objectifs de restauration correspondant aux 2 premiers niveaux d'ambition sur les 3 possibles : R1 et R2.

Le niveau R1 correspond à un objectif de restauration sur 1 compartiment de l'hydrosystème, souvent piscicole, dans un contexte où l'on ne peut pas réaliser de véritable opération de restauration fonctionnelle. Il peut être mis en œuvre dans l'emprise actuelle du lit mineur ou légèrement augmenté (faible emprise latérale). Les actions majoritairement utilisées consistent en la mise en place de structures (déflecteurs, petits seuils, aménagements

de berges en techniques végétales, minérales ou mixtes…). Ce type d'action est très utilisé en zones urbaines et périurbaines et dans tous les autres cas où les contraintes foncières sont importantes.

Le niveau R2 correspond à 1 objectif de restauration fonctionnelle plus globale intégrant l'amélioration des compartiments aquatiques et rivulaires intégrant donc le transport solide, l'habitat aquatique, la ripisylve, la nappe alluviale. Ce niveau d'ambition nécessite une emprise foncière plus importante (de 2 à 10 fois la largeur du lit mineur avant restauration). Il consiste en des actions de reméandrage de cours d'eau rectifié, écartement des digues, remise à ciel ouvert…

Enfin, le niveau R3 (non considéré dans cette partie), correspond à une ambition de restauration fonctionnelle complète de l'hydrosystème y compris de la dynamique d'érosion et du corridor fluvial.

Les indicateurs majoritairement utilisés pour l'évaluation de l'efficacité des travaux de restauration de l'habitat physique (types R1 et R2) sur les compartiments biologiques et physiques de l'écosystème (Tableau 1) ont été extraits du rapport technique effectué par Roni *et al.* (2005) pour la FAO (Food and Agriculture Organisation of the united nations). Ce rapport synthétise les effets de différentes techniques de réhabilitation des écosystèmes d'eau douce sur la base de 330 publications, dont beaucoup sont également présentées dans cette bibliographie annotée.

Tableau 1 : indicateurs communément utilisés dans la littérature pour l'évaluation de l'efficacité des actions de restauration de types R1 et R2 sur les compartiments physiques et biologiques de l'écosystème.

Compartiment	**indicateurs**	
habitat	Longévité des ouvrages	
	Changements des caractéristiques d'habitat (augmentation de …)	La quantité de débris ligneux
		L'hétérogénéité de l'habitat
		La complexité
		La rétention des sédiments
		La rétention de la matière organique
		La fréquence des mouilles
		La profondeur des mouilles
		La quantité de graviers de pontes
		La quantité d'abris, de refuges
biologique	Juvéniles de salmonidés migrateurs	Densité biomasse, croissance, condition, survie
	Salmonidés sédentaires	Densité biomasse, croissance, condition, survie
	Géniteurs de salmonidés	Frayères
	Non salmonidés	Densité biomasse, croissance, condition, survie
	Communauté piscicole	Diversité spécifique, biomasse
	Macroinvertébrés	Densité
		Diversité
		Groupes fonctionnels (Ex : mode d'alimentation)
		Rapidité de recolonisation
	Matière organique	Rétention MO
	Végétaux aquatiques	Diversité
		Croissance

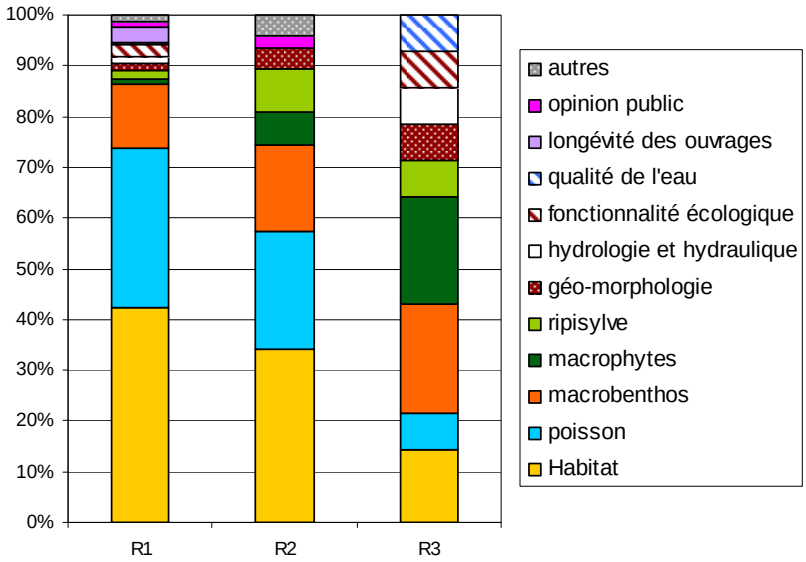

Figure 5 : Répartition des indicateurs utilisés pour l'évaluation en fonction du type de travaux de restauration effectué. Sur la base de 144 publications issues de revues scientifiques (entre 1949 et 2007) et traitant d'exemples d'évaluation de travaux de restauration de l'habitat physique des cours d'eau de type R1 (114 publications), R2 (23 publications) et R3 (7publications).

Concernant les aménagements de type R1 et R2, l'étude d'indicateurs appartenant aux 3 compartiments : physique, piscicole et macrobenthique est largement majoritaire (Figure 5). Cependant, nous pouvons remarquer à la fois une forte diversification de ces indicateurs ainsi qu'une nette évolution des informations recueillies à travers eux. En effet, le succès des travaux de restauration se mesure de plus en plus à travers l'évolution des fonctions de l'écosystème (transfert d'énergie, respiration, production, décomposition…).

Ainsi quelque soit le compartiment vivant étudié (poisson, macroinvertébrés, algues, macrophyte, ripisylve…) on tend à privilégier les approches aux échelles du peuplement, de guildes ou encore au niveau de la population. En effet, les indicateurs relatifs à ces échelles dépendent souvent de plusieurs facteurs, ce qui tend à diminuer leur variabilité (Minns *et al.*, 1996). En outre, l'étude de l'évolution des assemblages au sein des communautés peut également permettre l'identification de facteurs limitant supplémentaires à une plus large échelle (qualité d'eau, qualité des sédiments, déconnexion latérale, effets de la restauration elle-même…) (Suren & McMurtrie, 2005 ; Fuchs & Statzner, 2006 ; Spänhoff & Arle, 2007).

- Les moyens nécessaires ?

Peu d'articles traitent de l'aspect financier du suivi. Ainsi, il semblerait, d'après des interviews de gestionnaires en Europe et en Amérique du Nord, que le coût d'une évaluation pertinente de l'efficacité des travaux réalisés s'élève à environ 5 à 10% du coût total (Bratrich, 2004 *In* Woolsey *et al.*, 2007).

Bryant (1995) propose un suivi séquencé alternant des courtes phases intenses de récolte de données (3-5ans) et des phases plus longues de récoltes moins denses de données. Cette méthode a pour objectif de favoriser les suivis à long terme tout en restant efficace et en réduisant les coûts de réalisation.

CONCLUSION et PERSPECTIVES

A travers cette synthèse, nous prenons conscience à la fois de l'ampleur qu'a prise l'activité de restauration des écosystèmes aquatiques (explosion du nombre de projets, sommes investies toujours croissantes) et des récentes évolutions concernant ses pratiques et sa philosophie.

La tendance actuelle, est de mettre en place des plans de restauration qui portent davantage sur les écosystèmes et moins sur les espèces que l'on tends à privilégier (Minns *et al.*, 1996). Ainsi, les actions de restauration basées sur la manipulation directes des habitats sur des tronçons de rivière sont actuellement considérées comme très réductrices tant du point de vue de ces effets sur le compartiment biologique que de leur extension spatiale et temporelle. En effet ce type d'action est caractérisé par une faible étendue spatiale (tronçon de rivière) et les limites temporelles inhérentes aux structures construites. La majorités des auteurs suggèrent leur utilisation dans le cadre d'une stratégie de bassin versant en tant qu'action complémentaire (Kail *et al.*, 2007 ; Lake, 2005 ; Chapman, 1995 ; Kondolf, 1996).

D'une manière générale, la communauté scientifique tente actuellement de structurer les pratiques de restauration et d'harmoniser les méthodes d'évaluation.

Malgré tout, nous ne pouvons que déplorer le retard de cette discipline en France, qui malgré les nombreux retours d'expériences présents dans la littérature scientifique, réitère les mêmes erreurs. En effet, peu de projets semblent faire l'objet d'une étude avant projet sur la base de laquelle sont définis les objectifs et les modalités d'actions. En outre la pratique d'évaluation semble peu répandue et lorsqu'elle est effectuée, les résultats (succès ou échecs) et leçons tirées de ces expériences ne sont pas partagées avec les autres gestionnaires.

Sommaire des références par mots clés

- Type de publication -

- **Etude d'un (ou quelques) projet(s) ou exemples :**
  2, 4, 5, 6, 16, 18, 19, 20, 21, 24, 25, 26, 27, 29, 33, 34, 37, 38, 40, 42, 43, 45, 47, 48, 50, 54, 55, 59, 60, 61, 62, 63, 65, 66, 68, 69, 71, 73, 75, 76, 77, 79, 81, 82, 83, 84, 85, 86, 88, 92, 93, 95, 96, 97, 101, 103, 104, 105, 106, 109, 110, 111, 112, 116, 117, 120, 121, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 141, 142, 144, 145, 146, 147, 149, 150, 151, 152, 158, 159, 167, 168, 169, 170, 171, 173, 174, 176, 177, 179, 181, 182, 186, 187, 188, 189, 190, 191, 192, 193, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 207, 208, 210, 212, 213, 217, 220, 228, 229, 234, 241, 242.
  Publications concernant un même projet : 15 – 80 – 114, 163 – 164, 215 – 216.

- **Etude des divers projets réalisés sur une grande échelle (bases de données) :**
  1, 12, 13, 53, 72, 91, 99, 113, 143, 156, 161, 184, 214, 236.

- **Stratégie de bassin versant :**
  8, 9, 11, 22, 36, 44, 70, 74, 89, 118, 119, 148, 178, 180, 219, 221, 224.

- **Synthèse bibliographique, bibliographies annotées :** 3, 282, 283, 284.

- **Apports théoriques, scientifiques, techniques et méthodologiques pour la conception des projets (évaluation comprise) :**
  10, 14, 17, 23, 28, 41, 46, 51, 52, 56, 58, 61, 67, 78, 87, 90, 92, 94, 98, 100, 102, 103, 104, 110, 111, 112, 115, 117, 118, 119, 135, 136, 139, 142, 145, 153, 155, 160, 165, 194, 209, 211, 212, 218, 220, 221, 222, 223, 225, 229, 233, 235, 239.

- **Généralités et apports méthodologiques pour l'évaluation des projets :**
  7, 23, 26, 30, 31, 32, 34, 35, 39, 46, 49, 57, 64, 90, 98, 107, 108, 109, 111, 112, 115, 116, 118, 122, 131, 138, 140, 145, 157, 160, 166, 168, 172, 175, 182, 183, 185, 209, 226, 227, 232, 237, 238, 240

- **Description de modèles pouvant être utilisés dans le cadre de restauration de cours d'eau et de leur évaluation :** 154, 162, 206, 230, 231.

- Type de restauration -

- **R1** (objectif de restauration d'un compartiment de l'hydrosystème, souvent piscicole, dans un contexte où l'on ne peut réaliser une véritable opération de restauration fonctionnelle (mise en place de structures de diversification), souvent effectué dans l'emprise actuelle du lit mineur ou légèrement augmentée) :
  1, 2, 5, 14, 18, 19, 20, 21, 23, 25, 26, 27, 29, 33, 35, 37, 38, 39, 42, 43, 45, 47, 48, 50, 53, 56, 58, 59, 61, 62, 63, 68, 69, 71, 77, 78, 82, 83, 84, 85, 86, 87, 88, 92, 93, 95, 96, 97, 98, 103, 104, 110, 116, 117, 120, 121, 123, 124, 125, 126, 127, 129, 130, 132, 133, 134, 135, 136, 137, 142, 146, 147, 149, 150, 151, 152, 154, 159, 167, 170, 171, 172, 173, 174, 176, 177, 179, 181, 182, 186, 187, 188, 189, 190, 192, 193, 195, 196, 199, 200, 201, 202, 203, 204, 205, 207, 210, 212, 213, 217, 220, 225, 228, 229, 234, 241, 242

- **R2** (objectif de la restauration fonctionnelle plus globale. L'amélioration de tous les compartiments aquatiques et rivulaires est visée : transport solide, habitat aquatique, nappe alluviale, ripisylve. Ex : reméandrement, écartement des digues, remise à ciel ouvert…) :
  14, 16, 40, 54, 55, 65, 66, 73, 75, 76, 79, 81, 101, 106, 141, 142, 149, 169, 191, 197, 198, 215, 216

- **R3 :** (restauration fonctionnelle complète de l'hydrosystème y compris de la dynamique d'érosion et du corridor fluvial) :
  14, 15, 80, 105, 112, 114, 163, 164

- **Bassin versant :** 94, 102, 219

- Type de milieux -

- **Cours d'eau d'ordre ≤3 :** 17, 19, 38, 56, 59, 63, 106, 141, 151, 174, 182, 228

- **Cours d'eau d'ordre >3 :** 16, 17, 42, 56, 95, 96, 235

- **Cours d'eau salmonicole (sans précision de taille) :**
  8, 21, 39, 43, 47, 50, 74, 82, 83, 85, 103, 104, 110, 124, 189, 191, 192, 195, 217, 219, 220, 224, 242,

- **Cours d'eau côtiers (à salmonidés migrateurs) :** 37, 45, 58, 84, 130

- **Cours d'eau cyprinicole / eaux « chaudes » :**
  47, 81, 120, 171, 200, 201, 203, 204, 205, 218

- **Cours d'eau forestiers :** 124, 127, 197, 198, 199, 204

- **Cours d'eau alpins :** 67

- **Cours d'eau de plaine et de piedmont :** 57, 69, 71, 101, 149, 167

- **Cours d'eau sableux :** 5, 24, 42, 196, 198, 202

- **Cours d'eau à débits régulés :** 29, 36, 59, 79, 133, 134, 137, 170, 193, 229, 233

- **Cours d'eau chenalisés, rectifiés, incisés, dragués :**
  40, 42, 48, 54, 55, 59, 73, 86, 87, 88, 116, 120, 126, 127, 128, 129, 132, 142, 144, 145, 146, 147, 149, 159, 163, 164, 171, 196, 199, 200, 201, 202, 204, 210, 225, 228, 234, 242

- **Cours d'eau urbains :** 46, 121, 123, 153, 169, 190, 213, 215, 216, 231

- **Grands fleuves :** 32, 65, 75, 76, 175

- Grandes catégories d'indicateurs utilisés -

- **Structure habitationnelle vis-à-vis de la faune :**
  5, 8, 18, 19, 20, 21, 24, 25, 26, 28, 31, 34, 35, 37, 38, 40, 43, 45, 46, 47, 50, 51, 52, 55, 57, 58, 59, 60, 61, 62, 63, 65, 68, 69, 71, 77, 79, 81, 82, 83, 84, 85, 86, 87, 92, 93, 95, 96, 101, 103, 104, 106, 110, 116, 117, 120, 122, 123, 124, 125, 126, 129, 130, 131, 132, 135, 136, 137, 141, 142, 145, 146, 147, 149, 150, 151, 152, 159, 162, 164, 166, 167, 168, 169, 170, 171, 173, 174, 176, 177, 179, 182, 186, 187, 188, 189, 190, 191, 192, 193, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 212, 213, 215, 217, 218, 225, 228, 229, 232, 234, 237, 241, 242

- **Poissons :**
  5, 8, 18, 19, 20, 21, 24, 25, 29, 31, 33, 35, 37, 46, 47, 50, 52, 58, 62, 63, 64, 65, 66, 68, 79, 81, 82, 83, 84, 85, 86, 87, 88, 92, 93, 95, 96, 101, 103, 104, 105, 106, 120, 124, 126, 129, 130, 132, 133, 135, 136, 137, 141, 142, 144, 147, 150, 152, 158, 159, 163, 167, 168, 170, 171, 173, 174, 176, 177, 179, 182, 187, 190, 191, 192, 193, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 212, 217, 218, 228, 229, 241, 242

- **Macroinvertébrés :**
  15, 16, 26, 28, 33, 42, 43, 46, 48, 54, 55, 57, 59, 60, 61, 62, 66, 69, 71, 77, 95, 115, 116, 121, 123, 125, 126, 127, 131, 134, 141, 145, 146, 147, 149, 151, 169, 163, 164, 179, 182, 186, 210, 211, 213, 216, 225, 227

- **Macrophyte :** 6, 15, 40, 66, 71, 75, 76, 121, 163, 164,

- **Ripisylve :** 6, 18, 43, 73, 96, 105, 106, 158, 197, 198, 203

- **Processus géomorphologiques :** 24,25, 34, 38, 41, 46, 59, 66, 67, 69, 79, 82, 83, 88, 105, 108, 110, 114, 144, 194, 196, 202, 205, 210, 220

- **Hydrologie et Hydraulique :** 14, 114, 202, 205,

- **Fonctionnalité écologique : transfert de matière et d'énergie (souvent associé à la rétention en matière organique et transfert dans la chaîne alimentaire) :**
  34, 60, 92, 93, 127, 128, 145, 147, 151, 163, 182

- **Qualité de l'eau :** 46, 57, 80, 179, 186,

- **Longévité des structures :** 21, 56, 68, 84, 181, 188, 220,

- **Opinion publique :** 13, 53, 121, 169

- **Autres (activité pêche, mammifère, coût/bénéfice, occupation du sol, aspect paysager, algues, avifaune…) :** 13, 33, 97, 101, 105, 143, 182, 219.

Publications dans revues scientifiques :

- 1 - Alexander G.G. & Allan J., 2006. Stream Restoration in the Upper Midwest, U.S.A. Restoration Ecology, 14(4) : 595-604.

Keywords : ecosystem management • monitoring • restoration • stream improvement • watershed.

Abstract : Restoration activities intended to improve the condition of streams and rivers are widespread throughout the Upper Midwest, U.S.A. As with other regions, however, little information exists regarding types of activities and their effectiveness. We developed a database of 1,345 stream restoration projects implemented from the years 1970 to 2004 for the states of Michigan, Ohio, and Wisconsin in order to analyze regional trends in goals, presence of monitoring, spatial distribution, size, and cost of river restoration projects. We found that data on individual projects were fragmented across multiple federal, state, and county agencies, as well as nonprofit groups and consulting firms. The most common restoration goals reported for this region were in-stream habitat improvement, bank stabilization, water-quality management, and dam removal. The former two were most common in Michigan and Wisconsin, where salmonid fisheries enhancement appeared to be an important concern, whereas water-quality management was most frequent in Ohio. The most common restoration activities were the use of sand traps and riprap, and other common activities were related to the improvement of fish habitat. The median cost was $12,957 for projects with cost data, and total expenditures since 1990 were estimated at $444 million. Over time, the cost of individual projects has increased, whereas the median size has decreased, suggesting that restoration resources are being spent on smaller, more localized, and more expensive projects. Only 11% of data records indicated that monitoring was performed, and more expensive projects were more likely to be monitored. Standardization of monitoring and record keeping and dissemination of findings are urgently needed to ensure that dollars are well spent and restoration effectiveness is maximized.

- 2 - Alexander G.G. & Allan J., 2007. Ecological Success in Stream Restoration: Case Studies from the Midwestern United States. Environmental Management, 40(2):245-255.

Abstract : Despite rapid growth in river restoration, few projects receive the necessary evaluation and reporting to determine their success or failure and to learn from experience. As part of the National River Restoration Science Synthesis, we interviewed 39 project contacts from a database of 1,345 restoration projects in Michigan, Wisconsin, and Ohio to (1) verify project information; (2) gather data on project design, implementation, and coordination; (3) assess the extent of monitoring; and (4) evaluate success and the factors that may influence it. Projects were selected randomly within the four most common project goals from a national database: in-stream habitat improvement, channel reconfiguration, riparian management, and water-quality improvement. Roughly half of the projects were implemented as part of a watershed management plan and had some advisory group. Monitoring occurred in 79% of projects but often was minimal and seldom documented biological improvements. Baseline data for evaluation often relied on previous data obtained under regional monitoring programs using state protocols. Although 89% of project contacts reported success, only 11% of the projects were considered successful because of the response of a specific ecological indicator, and monitoring data were underused in project assessment. Estimates of ecological success, using three criteria from Palmer and others (2005), indicated that half or fewer of the projects were ecologically successful, markedly below the success level that project contacts self-reported, and sent a strong signal of the need for well-designed evaluation programs that can document ecological success.

- 3 - Allouche S., 2002. Synthèse bibliographique: Nature and functions of cover for riverine fish. Bulletin Français de la pêche et de la pisciculture, 365/366 : 297-324.

Keywords : cover • shelter • riverine fish • fish habitat.

Abstract : This review attempts to assess the nature and the role of cover for riverine fish assemblages. Although early identified as a key factor for fish distribution, especially for salmonids, cover (i.e. woody debris, undercut banks, boulders, turbidity...) still remains the variable least considered in the studies of fish habitat relationships. This is mainly due to the diversity of ecological functions of cover structures in fish assemblages. Cover structures are structuring components of fish habitat and contribute to the biological productivity of streams. But, at the individual scale, cover fulfils three main functions: protection against predators, visual isolation reducing competition, and hydraulic shelter. In fact, the use of cover by fish results from a trade-off between the costs and the benefits associated with its use. Although the relationships between fish and cover appear extremely complex and context-specific, a growing body of evidence highlights the potential role of cover for management purposes.

Résumé : *Nature et fonction du couvert pour les poissons lotiques*. Cet article décrit la typologie ainsi que les fonctions du couvert pour les poissons lotiques. Identifié très tôt comme un facteur explicatif de la distribution des poissons, principalement chez les salmonidés, le couvert (i.e. débris ligneux, sous-berges, blocs, turbidité...) demeure néanmoins la variable la moins considérée dans l'étude des relations habitat-poissons. Ceci s'explique notamment par les fonctions écologiques très diverses que le couvert remplit vis-à-vis des assemblages piscicoles. Les structures pourvoyeuses de couvert sont des agents structurants de l'habitat piscicole et contribuent à la productivité biologique des cours d'eau. Au niveau du microhabitat du poisson, le couvert remplit trois fonctions majeures : anti-prédation, isolation visuelle limitant la compétition, et abri hydraulique. En fait, l'utilisation du couvert par les poissons résulte d'un compromis entre les coûts et les bénéfices associés d'où l'extrême complexité de cette relation qui semble plutôt spécifique à un contexte donné. Malgré les difficultés d'extrapolation, de nombreux travaux mettent en évidence la signification écologique ainsi que l'utilisation potentielle du couvert pour une gestion optimale des ressources piscicoles.

- 4 - Andersen H.E. & Svendsen L.M., 1997. Suspended sediment and total phosphorus transport in a major Danish river: methods and estimation of the effects of a coming major restoration. Aquatic Conservation: Marine and Freshwater Ecosystems, 7(4) : 265-276.

Abstract :

1- The planned restoration of the lowermost 18 km of the Skjern river system (catchment area 2490 km^2) through re-meandering the river to its former course and the creation of a shallow lake and ponds is the largest river restoration project in Europe. An important aspect of the project planning and design has been to measure suspended sediment (SS) and total phosphorus (TP) transport in the project area, and to assess the inter-annual variation.

2- SS and TP concentrations were measured continuously (every fourth hour) from 1993 to 1995 in the River Skjern and its main tributary, the River Omme, using automatic sampling equipment (ISCO). In addition, discrete samples were collected monthly in the remaining five smaller tributaries. Estimated SS transport in the Skjern river system in 1994 and 1995 determined on the basis of continuous sampling was approximately 60% greater than that determined on the basis of discrete sampling. Empirical models for SS and TP transport were developed based on the data collected in this study and applied to a 31-year time series of daily discharge values. Mean annual transport amounted to 12 220 t SS and 100 t TP corresponding to 5 t SS km^{-2} yr^{-1} and 41 kg TP km^{-2} yr^{-1}, respectively.

3 - Assessment of the effects of the planned restoration project, based on measured transport and estimated SS and TP retention rates for different areas of the lower river system, revealed that SS and TP transport in the river will be reduced by 37% and 20%, respectively. Restoration will therefore considerably enhance the natural self-purification capacity of the river system. In addition, restoration will reduce nitrogen and ochre loading of Ringkjøbing Fjord, thereby improving environmental conditions, and re-meandering will improve habitat quality and diversity in the river system. The study stresses the importance of considering streams and riparian areas as an entity when evaluating the effects of restoration activities.

- 5 - Avery E.L., 1996. Evaluations of Sediment Traps and Artificial Gravel Riffles Constructed to Improve Reproduction of Trout in Three Wisconsin Streams. North American Journal of Fisheries Management, 16(2) : 282-293.

Abstract : The objective of this study was to determine if sediment traps installed alone or in conjunction with gravel spawning riffles would significantly improve natural reproduction of trout in 1.3–1.9-km segments of three Wisconsin streams. Each stream segment lacked adequate spawning habitat, and the presence of sand "dunes" suggested high sand bed load. The study covered 8 years (1984–1991). Little improvement was observed in the annual abundance of age-0 brown trout *Salmo trutta* or age-0 brook trout *Salvelinus fontinalis* during the 3–5-year period after installation and maintenance of a sediment trap in one stream and a sediment trap and gravel spawning riffle in two streams. Changes in average stream width and water depth below the sediment basins were masked by high variability in stream discharges in two of the three streams. In the third stream, average depth increased markedly, with a lesser increase in average width. The amount of gravel substrate did not increase significantly in any of the three streams, although the sand dunes appeared to decline in all streams. These evaluations provide no evidence that installation of sediment traps and gravel riffles will solve deficiencies in juvenile trout recruitment in Wisconsin streams where sand is the natural and prevailing parent material of the streambed and there is no prior record of successful spawning activities. Sediment traps and gravel riffles have greater management potential either in streams where past activities have increased sand sediment and degraded previously successful spawning habitat, or in otherwise undisturbed streams where successful spawning and juvenile habitat are better than in those selected in this study.

- 6 - Baattrup-Pedersen A., Riis T., Hansen H.O., Friberg N., 2000. Restoration of a Danish headwater stream: short-term changes in plant species abundance and composition. Aquatic Conservation: Marine and Freshwater Ecosystems, 10(1) : 13-23.

Keywords : stream restoration • headwaters • plant communities • diversity • riparian • species abundance • banks • stream valley.

Abstract :

1. This paper describes the short-term effects (2 years) of stream restoration on vascular plant communities in a 1.4 km upper reach of the River Gudenå, Denmark. The effects of restoration were assessed in terms of the abundance and composition of plant species in the stream, on the banks and in the stream valley.
2. Total species richness was similar before and after restoration, and comprised approximately 150 species representing 12% of the entire Danish vascular plant flora.
3. In the stream, total plant cover had not recovered to pre-restoration levels 2 years after restoration. Cover by submerged, amphibious and terrestrial species growing submerged decreased, as did the number of amphibious and terrestrial species growing submerged.
4. On the banks, total plant cover almost attained pre-restoration levels the second year after restoration. The plant communities changed from dominance by non-riparian species to more diverse communities with a greater number and increased cover of riparian gramineous species requiring a higher soil moisture content.
5. In the valley, the plant communities only changed slightly after restoration, although growth of riparian species was enhanced on the southern side of the stream.

- 7 - Bash J.S. & Ryan C.M., 2002. Stream Restoration and Enhancement Projects: Is Anyone Monitoring? Environmental management, 29(6) : 877-885.

Keywords : monitoring • stream restoration • fisheries enhancement • project goals.

Abstract : Declines in salmon stocks and general watershed health in Washington State, USA, have led to an increase in stream restoration and enhancement projects initiated throughout the state. The increasing number of projects has also raised questions regarding the monitoring of these efforts. Project managers receiving hydraulic project approvals (HPAs) were surveyed to determine whether monitoring was taking place on their projects. About half the project managers surveyed reported the collection of baseline data and the use of biological, physical, chemical, or other water quality

measures for their projects. Of those who reported collection of monitoring data, only 18% indicated that monitoring was required. Respondents were also asked to rank the importance of various project goals on a Likert scale. Project managers with projects focusing on "engineering" goals (e.g., roadbed stabilization) were less likely than other project managers to collect baseline monitoring data. Project managers with projects focusing on "restoration/ecological" or "fisheries" goals were more likely than other project managers to collect monitoring measures. Although monitoring appears to be taking place in slightly more than half of the projects surveyed, the nature of the data collected varies widely across projects, and in most cases the monitoring effort is voluntary. This suggests that project sponsors, funders, and managers must consider the issues involved in requiring appropriate monitoring, establishing standardized monitoring guidelines, the time frames in which to monitor, providing other incentives for conducting monitoring, and ensuring adequate funding for monitoring efforts.

- 8 - Beechie T., Beamer E. & Wasserman L., 1994. Estimating Coho Salmon Rearing Habitat and Smolt Production Losses in a Large River Basin, and Implications for Habitat Restoration. North American Journal of Fisheries Management, 14(4) : 797-811.

Abstract : To develop a habitat restoration strategy for the 8,270-km^2 Skagit River basin, we estimated changes in smolt production of coho salmon *Oncorhynchus kisutch* since European settlement began in the basin, based on changes in summer and winter rearing habitat areas. We assessed changes in coho salmon smolt production by habitat type and by cause of habitat alteration. We estimated that the coho salmon smolt production capacity of summer habitats in the Skagit River basin has been reduced from 1.28 million smolts to 0.98 million smolts (–24%) and that the production capacity of winter habitats has been reduced from 1.77 million to 1.17 million smolts (–34%). The largest proportion of summer non-main-stem habitat losses has occurred in side-channel sloughs (41%), followed by losses in small tributaries (31%) and distributary sloughs (29%). The largest loss of winter habitats has occurred in side-channel sloughs (52%), followed by losses in distributary sloughs (37%) and small tributaries (11%). By type of impact, hydromodification (diking, ditching, dredging) associated with agricultural and urban lands accounts for 73% of summer habitat losses and 91% of winter habitat losses. Blocking culverts on small tributaries account for 13% of the decrease in summer habitat and 6% of the decrease in winter habitat. Forestry activities account for 9% of summer habitat losses and 3% of winter habitat losses. Limitations of the analysis and implications for developing a habitat restoration strategy are discussed

- 9 - Beechie T. & Bolton S., 1999. An Approach to Restoring Salmonid Habitat-forming Processes in Pacific Northwest Watersheds. Fisheries, 24(4) : 6-15.

Abstract : We present an approach to diagnosing salmonid habitat degradation and restoring habitat-forming processes that is focused on causes of habitat degradation rather than on effects of degradation. The approach is based on the understanding that salmonid stocks are adapted to local freshwater conditions and that their environments are naturally temporally dynamic. In this context, we define a goal of restoring the natural rates and magnitudes of habitat-forming processes, and we allow for locally defined restoration priorities. The goal requires that historical reconstruction focus on diagnosing disruptions to processes rather than conditions. Historical reconstruction defines the suite of restoration tasks, which then may be prioritized based on local biological objectives. We illustrate the use of this approach for two habitat-forming processes: sediment supply and stream shading. We also briefly contrast this approach to several others that may be used as components of a restoration strategy.

- 10 - Bednarek A.T., 2001. Undamming Rivers: A Review of the Ecological Impacts of Dam Removal. Environmental Management, 27(6) : 803-814.

Keywords : dam removal • restoration • mitigation • flow regime • sediment • fish passage.

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 conditions 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. Preremoval 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.

- 11 - Beechie T.J., Pess G., Kennard P., Bilby R.E & Bolton S., 2000. Modeling Recovery Rates and Pathways for Woody Debris Recruitment in Northwestern Washington Streams. North American Journal of Fisheries Management, 20(2) : 436-452.

Abstract : We modeled large woody debris (LWD) recruitment and pool formation in northwestern Washington streams after simulated stand-clearing disturbance using two computer models: Forest Vegetation Simulator for stand development and Riparian-in-a-Box for LWD recruitment, depletion, and pool formation. We evaluated differences in LWD recruitment and pool formation among different combinations of channel size, successional pathway, and stand management scenario. The models predict that time to first recruitment of pool-forming LWD is about 50% shorter for red alder *Alnus rubra* than for Douglas-fir *Pseudotsuga menziesii* at all channel widths. Total LWD abundance increases faster in red alder stands than in Douglas-fir stands but declines rapidly after 70 years as the stand dies and pieces decompose. Initial recovery is slower for Douglas-fir stands, but LWD recruitment is sustained longer. Total LWD abundance increases faster with decreasing channel size, and pool abundance increases faster with decreasing channel width and increasing channel slope. The models predict that thinning of the riparian forest does not increase recruitment of pool-forming LWD where the trees are already large enough to form pools in the adjacent channel and that thinning reduces the availability of adequately sized wood. Thinning increases LWD recruitment where trees are too small to form pools and, because of reduced competition, trees more rapidly attain pool-forming size. On channels less than 20 m wide, thinning of red alder and underplanting shade-tolerant conifers will reduce near-term alder recruitment and increase long-term conifer recruitment. However, the same treatment on channels more than 20 m wide may increase both near-term and long-term recruitment. Compared with the natural fire regime, timber harvest rotations of 40–80 years during the past century have reduced the percentage of riparian stands that can provide LWD of pool-forming size to streams, especially in channels at least 20 m wide.

- 12 - Bernhardt E.S., Palmer M.A., Allan J.D., Alexander G., Barnas K., Brooks S., Carr J., Clayton S., Dahm C., Follstad-Shah J., Galat D., Gloss S., Goodwin P., Hart D., Hassett B., Jenkinson R., Katz S., Kondolf G.M., Lake P.S., Lave R., Meyer J.L., O'Donnell T.K., Pagano L., Powell B. & Sudduth E., 2005. Synthesizing U.S. River Restoration Efforts. Science, 308(5722) : 636 – 637.

Abstract : The authors of this Policy Forum developed a comprehensive database of >37,000 river restoration projects across the United States. Such projects have increased exponentially over the past decade with more than a billion dollars spent annually since 1990. Most are intended to enhance water quality, manage riparian zones, improve in-stream habitat, allow fish passage, and stabilize stream banks. Only 10% of project records document any form of project monitoring, and little if any of this information is either appropriate or available for assessing the ecological effectiveness of restoration activities.

- 13 - Bernhardt E.S., Sudduth E.B., Palmer M.A, Allan J.D., Meyer J.L., Alexander G., Follastad-Shah J., Hassett B., Jenkinson R., Lave R., Rumps J. & Pagano L., 2007. Restoring Rivers One Reach at a Time: Results from a Survey of U.S. River Restoration Practitioners. Restoration Ecology, 15(3) : 482–493.

Abstract : Despite expenditures of more than 1 billion dollars annually, there is little information available about project motivations, actions, and results for the vast majority of river restoration efforts. We performed confidential telephone interviews with 317 restoration project managers from across the United States with the goals of (1) assessing project motivations and the metrics of project evaluation and (2) estimating the proportion of projects that set and meet criteria for ecologically successful river restoration projects. According to project managers, ecological degradation typically motivated restoration projects, but post-project appearance and positive public opinion were the most commonly used metrics of success. Less than half of all projects set measurable objectives for their projects, but nearly two-thirds of all interviewees felt that their projects had been "completely successful." Projects that we classified as highly effective were distinct from the full database in that most had significant community involvement and an advisory committee. Interviews revealed that many restoration practitioners are frustrated by the lack of funding for and emphasis on project monitoring. To remedy this, we recommend a national program of strategic monitoring focused on a subset of future projects. Our interviews also suggest that merely conducting and publishing more scientific studies will not lead to significant improvements in restoration practice; direct, collaborative involvement between scientists, managers, and practitioners is required for forward progress in the science and application of river restoration.

- 14 - Bhuiyan F., Hey R.D., Wormleaton P.R., 2007. Hydraulic Evaluation of W-Weir for River Restoration. Journal of Hydraulic Engineering., 133(6) : 596-609.

Abstract : Various structural measures have been advocated for river restoration and habitat improvement schemes. The W-weir is one such structure that can be used in mobile bed alluvial rivers to diversify habitat and provide grade control. Laboratory studies have been carried out in a large-scale meandering channel with a mobile bed to investigate their effects on flow and sediment transport processes. A W-weir placed immediately downstream of a riffle section created a strongly three-dimensional flow pattern and high-turbulence zones. Two adjacent scour holes of different depths and substrate are formed under clearwater and live bed conditions. The continuity of sediment transport along the channel was not interrupted by the structure and the upstream afflux is minimal. Overbank flow significantly influenced the action of the weir and the scour hole was shifted closer to the structure. In a relatively tight bend followed by a short crossover reach, the weir may affect bed load transport pathways in the downstream bend. Finally, the study provides insights to guide their design for restoration projects.

- 15 - Biggs J., Corfield A., Grøn P., Hansen H.O., Walker D., Whitfield M. & Williams P., 1998. Restoration of the rivers Brede, Cole and Skerne: a joint Danish and British EU-LIFE demonstration project, V - short-term impacts on the conservation value of aquatic macroinvertebrate and macrophyte assemblages. Aquatic Conservation: Marine and Freshwater Ecosystems, 8(1) : 241-255.

Keywords : river • habitat restoration • aquatic macroinvertebrates • macrophytes • downstream impact • colonization • species richness • rarity.

Abstract :

1. This paper describes the short-term effects of river restoration on the wetland macrophyte and aquatic macroinvertebrate assemblages of two rivers, the R. Brede (Denmark) and the R. Cole (UK). The effects of the restoration work were assessed in terms of changes in species richness, rarity and abundance on (i) the restored sections and (ii) potentially impacted sections downstream of the restoration works.
2. In the restored areas of both rivers the species richness of wetland macrophyte assemblages recovered to at least pre-restoration levels 1-2 years after restoration. Macroinvertebrate species richness recovery was more variable. The abundance of macroinvertebrates and wetland

macrophytes generally recovered less rapidly than species richness. For wetland macrophytes, the recovery process was enhanced by the presence of refugia.

3. Uncommon invertebrates were slower to recolonize the restored sections in the year after restoration (monitored on the R. Cole only). The number of uncommon wetland macrophyte species recorded was similar throughout the restoration and recovery period.
4. Potentially impacted sections of the river up to 1.2 km downstream of the restored area showed a relative decline in invertebrate species richness 1-2 months after the physical works were completed, but little difference from pre-restoration levels after 1 year. Plant surveys downstream of the restored area showed no evidence of a significant change in species richness, neither was there evidence that uncommon plant or invertebrate species were affected by downstream impacts (sediment or nutrient release) due to restoration.

- 16 - Bij De Vaate, A., Klink A.G., Greijdanus-Klaas M., Jans L.H., Oosterbaan J. & Kok F., 2007. Effects of habitat restoration on the macroinvertebrate fauna in a foreland along the river waal, the main distributary in the rhine delta. River research and applications, 23(2) : 171-183.

Keywords : main River • invertebrata • habitat ; • environment quality • delta • fauna • ecological recovery.

Abstract : River engineering in the Rhine delta and water pollution have been major threats for the ecological functioning of the river in The Netherlands. To mitigate effects of river engineering, secondary channel construction in the forelands along the existing distributaries is considered to be an important measure for river restoration. These areas are the remnants of the former Rhine floodplain and the only area where habitat restoration is possible due to the river functions assigned. Secondary channel construction in the area called 'Gamerensche Waarden' was taken as an example to show effects of habitat restoration on the macroinvertebrate fauna. Totally 322 macroinvertebrate taxa were found during the monitoring period. During the first 3 years species richness in the area increased rapidly due to colonization processes in the channels following habitat development. After that period total number of taxa found in the channels stabilized at around 170. A clear positive relationship was demonstrated between habitat quality and species richness. Furthermore, the density of exotic species in the secondary channels was less than in the groyne fields of the main channel. The relatively low number of taxa in polluted habitats could be explained by the presence of the PCB 28 congener.

- 17 - Bilby R.E. & Ward J.W., 1989. Changes in Characteristics and Function of Woody Debris with Increasing Size of Streams in Western Washington. Transactions of the American Fisheries Society, 118(4) : 368-378.

Abstract : In second- to fifth-order streams that drain old-growth timber in western Washington, characteristics and function of woody debris changed in relation to stream size. Average diameter, length, and volume of pieces of wood increased as stream size increased, whereas the frequency of occurrence of woody debris decreased. In streams with channel widths less than 7 m, 40% of the pieces of debris were oriented perpendicularly to the axis of flow; in streams with channel widths over 7 m, more than 40% of the pieces were oriented downstream. The types of pools most commonly associated with pieces of wood changed from plunge pools in small streams (42%) to debris scour pools in larger systems (62%). Pool area was correlated with the volume of the piece of wood forming the pool in streams of all sizes. However, this relationship was most evident in larger channels. Nearly 40% of the pieces of wood in channels less than 7 m wide were associated with sediment accumulations. Less than 30% of the pieces retained sediment in channels from 7 to 10 m wide, and less than 20% retained sediment in channels greater than 10 m wide. Surface area of sediment accumulations and the volume of the piece of wood forming the accumulation were related in all streams, but the relationship was clearest in the larger channels. Accumulations of particulate organic matter associated with woody debris were more frequent in small streams but were larger in large streams. No relationship was observed between the volume of fine particulate organic matter accumulated by a piece of wood and the piece of wood's volume.

- 18 - Bilby R.E. & Fransen B.R., 1992. Effect of habitat enhancement and canopy removal on the fish community of a headwater stream. Northwest Science, 66(2) : 137.

Abstract : The riparian trees along a 2km section of stream in western Oregon were logged in 1985, in violation of forest practice regulations. As part of the judgement against the landowner, wood was placed in the channel to improve habitat in 1988. Fish populations and habitat have been monitored since 1986 at 3 sites: the enhanced area, an non-enhanced reach without a canopy and a non-enhanced reach with a canopy. Pool area increased 20% as a result of the wood addition at the enhanced site. Pool area during summer also increased at the site with the canopy due to beaver activity. Speckled dace (*Rhinichthys osculus*) have exhibited the greatest response, increasing in numbers at all 3 sites, with greatest gains in the enhanced reach. Salmonid density at all three sites also has increased since 1988. Age 0+ steelhead (*Oncorhynchus mykiss*) exhibit an inverse relationship between density and growth.

- 19 - Binns N.A., 1994. Long-Term Responses of Trout and Macrohabitats to Habitat Management in a Wyoming Headwater Stream. North American Journal of Fisheries Management, 14(1) : 87-98.

Abstract : After 111 habitat improvement devices and 2,150 ft of riprap were installed (1973–1977) in Beaver Creek, northeast Wyoming, the stream developed a narrower channel with deep pools that helped brook trout *Salvelinus fontinalis* survive low flows. After 7 years, brook trout 6 in and longer had increased 1,814%, brook trout less than 6 inches had increased 1,462%, and the total population density had reached 2,074/mi (268 lb/acre). By 1990, after extended drought during the 1980s, the brook trout population had dropped to 222/mi (41 lb/acre), but this level was 90% better than before habitat development. Over 90% ofthe devices remained fully functional 18 years after installation, even though some of them were esthetically displeasing due to exposure of logs and planks. Wooden plunges were comparatively easy to install and dug good pools. Deflectors worked better directing currents than digging pools. Wood bank overhangs and overpour (Hewitt) ramps provided variable results. were hard to install, were apt to be damaged by floods, and are not recommended for Wyoming streams.

- 20 - Binns N.A. & Remmick R., 1994. Response of Bonneville Cutthroat Trout and Their Habitat to Drainage-Wide Habitat Management at Huff Creek, Wyoming. North American Journal of Fisheries Management, 14(4) : 669-680.

Abstract : Beginning in 1978, in an effort to restore Bonneville cutthroat trout *Oncorhynchus clarki utah*, 68 instream habitat structures and 3,760 ft of rock riprap were installed in the Huff Creek (Wyoming) drainage, and livestock was controlled through exclosures and herding. Drainage-wide cutthroat trout abundance and biomass peaked in 1984 at 456 trout/mi and 56 lb/acre. The largest population (1984; 685 trout/mi, 82 lb/acre) occurred at the site containing instream structures within an exclosure. By 1989, mean cutthroat trout numbers (170 trout/mi) were significantly higher (P = 0.01) than in 1978 (35 trout/mi), despite severe drought in 1987–1989 and a 75–100 year flood in 1984. Drainage-wide Habitat Quality Index scores were significantly higher and total cover was significantly greater in 1989 than in 1978, but bank stability was not significantly improved. However, banks armored with machine-placed rocks became stable; in contrast, natural healing was slow where rocks were not used. Cutthroat trout abundance was correlated to the previous year's stream discharge, the quantity of cover, and pool area. Plunge pools created by instream structures were deeper than natural pools and greatly aided fishery rejuvenation.

- 21 - Binns N.A., 2004. Effectiveness of Habitat Manipulation for Wild Salmonids in Wyoming Streams. North American Journal of Fisheries Management, 24(3) : 911-921.

Abstract : Habitat manipulation is commonly used to enhance habitat and stocks of fluvial trout of the genera *Oncorhynchus*, *Salmo*, and *Salvelinus*, but questions have been raised about the effectiveness of such work. Consequently, I analyzed wild trout abundance, biomass, and habitat before and after habitat manipulations among 30 projects done by the Wyoming Game and Fish Department.

Abundance and biomass of trout increased following habitat manipulation among most of the projects. Excessive angler harvest prevented an increase at three projects, and drought hindered fish response in a fourth stream. At a fifth project, the trout population decreased after intense cattle grazing degraded project structures. Instream structures proved durable. Only one project, which featured wire trash catchers in a fourth-order mountain stream, suffered failure of habitat manipulation devices. Cover for trout and residual pool depth significantly increased following projects, whereas eroding banks significantly decreased. Both timber and log check dams consistently produced good pools, but rock check dams did not. Mean per project cost statewide was US$39,230/mi. These results demonstrate that well-built, properly located, and properly maintained instream structures can provide better habitat and increase stocks of trout in carefully selected reaches, thus satisfying public and agency expectations for fishery improvement and gaining time to correct watershed problems.

- 22 - Bohn B.A. & Kershner J.L., 2002. Establishing aquatic restoration priorities using a watershed approach. Journal of Environmental Management, 64(4) : 355-363.

Keywords: watershed analysis • stream habitat improvement • stream biota • watersheds • geomorphology • stream classification • aquatic restoration.

Abstract : Since the passage of the Clean Water Act in 1972, the United States has made great strides to reduce the threats to its rivers, lakes, and wetlands from pollution. However, despite our obvious successes, nearly half of the nation's surface water resources remain incapable of supporting basic aquatic values or maintaining water quality adequate for recreational swimming. The Clean Water Act established a significant federal presence in water quality regulation by controlling point and non-point sources of pollution. Point-sources of pollution were the major emphasis of the Act, but Section 208 specifically addressed non-point sources of pollution and designated silviculture and livestock grazing as sources of non-point pollution. Non-point source pollutants include runoff from agriculture, municipalities, timber harvesting, mining, and livestock grazing. Non-point source pollution now accounts for more than half of the United States water quality impairments. To successfully improve water quality, restoration practitioners must start with an understanding of what ecosystem processes are operating in the watershed and how they have been affected by outside variables. A watershed-based analysis template developed in the Pacific Northwest can be a valuable aid in developing that level of understanding. The watershed analysis technique identifies four ecosystem scales useful to identify stream restoration priorities: region, basin, watershed, and site. The watershed analysis technique is based on a set of technically rigorous and defensible procedures designed to provide information on what processes are active at the watershed scale, how those processes are distributed in time and space. They help describe what the current upland and riparian conditions of the watershed are and how these conditions in turn influence aquatic habitat and other beneficial uses. The analysis is organized as a set of six steps that direct an interdisciplinary team of specialists to examine the biotic and abiotic processes influencing aquatic habitat and species abundance. This process helps develop an understanding of the watershed within the context of the larger ecosystem. The understanding gained can then be used to identify and prioritize aquatic restoration activities at the appropriate temporal and spatial scale. The watershed approach prevents relying solely on site-level information, a common problem with historic restoration efforts. When the watershed analysis process was used in the Whitefish Mountains of northwest Montana, natural resource professionals were able to determine the dominant habitat forming processes important for native fishes and use that information to prioritize, plan, and implement the appropriate restoration activities at the watershed scale. Despite considerable investments of time and resources needed to complete an analysis at the watershed scale, the results can prevent the misdiagnosis of aquatic problems and help ensure that the objectives of aquatic restoration will be met.

- 23 - Bond N.R. & Lake P.S., 2003. Local habitat restoration in streams: Constraints on the effectiveness of restoration for stream biota. Ecological Management & Restoration, 4 (3), 193–198.

Abstract : The restoration of physical habitat has emerged as a key activity for managers charged with reversing the damage done by humans to streams and rivers, and there has been a great expenditure of time, money and other resources on habitat restoration projects. Most restoration projects appear to assume that the creation of habitat is the key to restoring the biota ('the field of

dreams hypothesis'). However, in many streams where new habitat is clearly required if populations and communities are to be restored, there may be numerous other factors that cause the expected link between habitat and biotic restoration to break down. We discuss five issues that are likely to have a direct bearing on the success, or perceived success of local habitat restoration projects in streams: (i) barriers to colonization, (ii) temporal shifts in habitat use, (iii) introduced species, (iv) long-term and large-scale processes, and (v) inappropriate scales of restoration. The purpose of the study was primarily to alert ecologists and managers involved in stream habitat restoration to the potential impacts of these issues on restoration success. Furthermore, the study highlights the opportunities provided by habitat restoration for learning how the factors we discuss affect populations, communities and ecosystems.

- 24 - Borg D., Rutherfurd I. & Stewardson M., 2007. The geomorphic and ecological effectiveness of habitat rehabilitation works: Continuous measurement of scour and fill around large logs in sand-bed streams. Geomorphology, 89(1-2) : 205-216.

Keywords: habitat • scour • continuous scour monitoring • geomorphic effectiveness • wood.

Abstract : Geomorphologists, ecologists and engineers have all contributed to stream rehabilitation projects by predicting the physical effect of habitat restoration structures. In this study we report the results of a stream rehabilitation project on the Snowy River, SE Australia; that aims to improve fish habitat and facilitate migration associated with scour holes around large wood in the streambed. Whilst engineering models allow us to predict maximum scour, the key management issue here was not the maximum scour depth but whether the holes persisted at a range of flows, and if they were present when fish actually required them. This led to the development of a new method to continuously monitor scour in a sand-bed, using a buried pressure transducer. In this study we monitored fluctuations in the bed level below three large logs (1 m diameter) on the Snowy River. Each log had a different scour mechanism: a plunge pool, a horseshoe vortex (analogous to a bridge pier), and a submerged jet beneath the log. The continuous monitoring demonstrated a complex relationship between discharge and pool scour. The horseshoe vortex pool maintained a constant level, whilst, contrary to expectations, both the plunge pool and the submerged jet pool gradually filled over the 12 months. Filling was associated with the average rise in flows in winter, and occurred despite several freshes and discharge spikes. The plunge pool showed the most variation, with bed levels fluctuating by over 1 m. A key factor in pool scour here may not be the local water depth at the log, but the position of the log in relation to larger scale movements of sand-waves in the stream. These results question assumptions on the relative importance of small floods or channel-maintenance flows that lead to beneficial scour around large wood in sand-bed streams. Further, the continuous measurement of scour and fill around the logs suggested the presence of pool scour holes would have met critical requirements for Australian bass (*Macquaria novemaculeata*) during the migration period, whereas less-frequent monitoring typical of rehabilitation trials would have suggested the contrary. The results of this study have demonstrated that geomorphic effectiveness is not always synonymous with biological effectiveness. Whilst physical models emphasise extreme changes, such as maximum scour, the key biological issue is whether scour occurs at the critical time of the life cycle. Continuous measurement of sand levels is an example of a geomorphic technique that will help to develop models that predict biologically meaningful processes, not just extremes.

- 25 - Brooks A.P., Gehrke P.C., Jansen J.D. & Abbe T.B., 2004. Experimental reintroduction of woody debris on the Williams River, NSW: geomorphic and ecological responses. River Research and Applications, 20(5) : 513-536.

Keywords : river rehabilitation • woody debris • geomorphic recovery • complex response • meso-habitat • micro-habitat.

Abstract : A total of 436 logs were used to create 20 engineered log jams (ELJs) in a 1.1 km reach of the Williams River, NSW, Australia, a gravel-bed river that has been desnagged and had most of its riparian vegetation removed over the last 200 years. The experiment was designed to test the effectiveness of reintroducing woody debris (WD) as a means of improving channel stability and recreating habitat diversity. The study assessed geomorphic and ecological responses to introducing woody habitat by comparing paired test and control reaches. Channel characteristics (e.g. bedforms,

bars, texture) within test and control reaches were assessed before and after wood placement to quantify the morphological variability induced by the ELJs in the test reach. Since construction in September 2000, the ELJs have been subjected to five overtopping flows, three of which were larger than the mean annual flood. A high-resolution three-dimensional survey of both reaches was completed after major bed-mobilizing flows. Cumulative changes induced by consecutive floods were also assessed. After 12 months, the major geomorphologic changes in the test reach included an increase in pool and riffle area and pool depth; the addition of a pool-riffle sequence; an increase by 0.5-1 m in pool-riffle amplitude; a net gain of 40 m^3 of sediment storage per 1000 m^2 of channel area (while the control reach experienced a net loss of 15 m^3/1000 m^2 over the same period); and a substantial increase in the spatial complexity of bed-material distribution. Fish assemblages in the test reach showed an increase in species richness and abundance, and reduced temporal variability compared to the reference reach, suggesting that the changes in physical habitat were beneficial to fish at the reach scale.

- 26 - Brooks S.S., Palmer M.A., Cardinale B.J., Swan C.M. & Ribblett S., 2002. Assessing Stream Ecosystem Rehabilitation: Limitations of Community Structure Data. Restoration Ecology, 10 (1) : 156–168.

Abstract : Inappropriate land use practices, pollutants, exploitation, and overpopulation have simplified stream habitats and degraded water quality worldwide. Management agencies are now being tasked to ameliorate impacts and restore stream "health," yet there is a dearth of rigorous scientific methods and theory on which to base sound restoration design and monitoring. Despite this, many localized restoration projects are being constructed to stabilize erosion and enhance habitat heterogeneity in streams. Many restoration attempts adopt the paradigm that increasing habitat heterogeneity will lead to restoration of biotic diversity, yet there have been few studies that have manipulated *variation* of a physical parameter independent of the mean to isolate the effects of heterogeneity *per se*. We conducted a field experiment to mimic restoration of habitat heterogeneity in a shallow. stony stream. By using an experimental approach rather than a detailed assessment of existing restoration work, we were able to control the starting conditions of replicate riffles so that organism responses could be unambiguously attributed to the heterogeneity treatments. We successfully manipulated the *variability* of streambed particle sizes and consequently near-bed flow characteristics of entire riffles. These factors define axes of habitat heterogeneity at scales relevant to the resident macroinvertebrate fauna. Despite this, we were unable to distinguish differences in community structure between high and low habitat heterogeneity treatments. Power analysis indicated that macroinvertebrate populations were more sensitive to individual site conditions at each riffle than to the heterogeneity treatments, suggesting that increasing habitat heterogeneity may be an ineffective technique if the restoration goals are to promote macroinvertebrate recovery in denuded streams. With extremely high variability between replicate riffles, monitoring programs for localized restoration projects or point source impacts are unlikely to detect gradual shifts in community structure until the differences between the reference and treatment sites are extreme. Innovative measurement of other parameters, such as ecosystem function variables (e.g., production, respiration, decomposition), may be more appropriate indicators of change at local scales.

- 27 - Brooks S.S. & Lake P.S., 2007. River Restoration in Victoria, Australia: Change is in the Wind, and None too Soon. Restoration Ecology, 15(3) : 584–591.

Abstract : Stream restoration has become a multibillion dollar industry worldwide, yet there are few clear success stories and the scientific basis for effective stream restoration remains uncertain. We compiled data on completed river restoration projects from four management authorities in Victoria, Australia, to examine how the available data could inform the science of restoration ecology in rivers, and thus improve future restoration efforts. We found that existing data sources are limited and much historical information has been lost through industry restructuring and poor data archiving. Examining records for 2,247 restoration projects, we found that riparian management projects were the most common, followed by bank stabilization and in-stream habitat improvement. Only 14% of the project records indicated that some form of monitoring was carried out. It is evident that overall there is little scientific guidance and little or no monitoring and evaluation of the projects for which we had information. However, recent advances with mandatory, statewide reporting and an increased emphasis on project design and monitoring strongly suggest that the design, implementation,

monitoring, and reporting of stream restoration projects have improved in recent years and will continue to do so.

- 28 - Brown B.L., 2003. Spatial heterogeneity reduces temporal variability in stream insect communities. Ecology Letters, 6(4) : 316-325.

Abstract : Although all natural systems are heterogeneous, the direct influence of spatial heterogeneity on most ecological variables is unknown. In many systems, spatial heterogeneity is positively correlated with both microhabitat refugia and species richness. Both an increased number of microhabitat refugia and the effects of statistical averaging via increased species richness should lead to an inverse relationship between spatial heterogeneity and variability in community composition. To test this prediction, I measured diversity and temporal variability of invertebrate communities in a northern New Hampshire stream along a natural gradient of spatial heterogeneity formed by variation in stream substrates. On average, there was a 42% decrease in community variability along a gradient of increasing heterogeneity. This pattern was robust to changes in metrics of both heterogeneity and community variability. There was also a significant positive relationship between taxon richness and spatial heterogeneity with predicted taxon richness increasing *c*. 1.5× along the heterogeneity gradient. By resampling community abundance data, I estimated that statistical averaging accounted for only 4% of the observed decrease in community variability in this study. I concluded that the remaining decrease was very likely explained by a greater number of refugia from predation and/or flooding in high-heterogeneity habitats. The results of this study suggest that maximizing heterogeneity in ecological restoration programmes may promote temporally stable and diverse communities and may aid in responsible management of aquatic resources.

- 29 - Brusven M.A., Meehan W.R. & Ward J.F., 1986. Summer Use of Simulated Undercut Banks by Juvenile Chinook Salmon in an Artificial Idaho Channel. North American Journal of Fisheries Management, 6(1) : 32-37.

Abstract : The effects of introducing simulated undercut stream banks on the distribution of juvenile chinook salmon (*Oncorhynchus tshawytscha*) were studied in a naturally vegetated, flow-regulated channel in Idaho in 1980 and 1981. In all tests, mean fish weight was greater in covered than in open sections. Preference for the covered versus uncovered experimental sections was highly significant during July and August tests. For all tests combined, 82% of the fish by numbers and 85% by biomass were collected in covered sections. The results suggest that undercut banks, as simulated by artificial shelters, are an important summer habitat component for juvenile chinook salmon that should be carefully evaluated by the manager.

- 30 - Bryant M.D., 1995. Pulsed Monitoring for Watershed and Stream Restoration. Fisheries, 20(11) : 6-13.

Abstarct : Long-term habitat degradation has increased public recognition of the need for watershed and stream habitat restoration. With such recognition is the demand for accountability, but the effects of restoration and recovery of watersheds are complex and long-term. A monitoring program that provides sufficient information to evaluate the effectiveness of these efforts will be expensive. A pulsed monitoring strategy that consists of a series of short-term (3–5 years), high-intensity studies separated by longer periods (10–15 years) of low-density data collection can provide an effective means of implementing a long-term monitoring program with a reasonable degree of success and cost.

- 31 - Bryant M.D., Edwards R.T. & Woodsmith R.D., 2005. An approach to effectiveness monitoring of floodplain channel aquatic habitat: salmonid relationships. Landscape and Urban Planning 72(1-3) : 157-176.

Keywords : aquatic habitat • effectiveness monitoring • anadromous salmonids • lotic productivity.

Abstract : Rivers and streams that support anadromous salmonids are an important part of land management planning in southeastern Alaska and the Pacific Northwest of North America. Land managers and planners require a consistent set of protocols that include both the physical and biological aspects of the stream for effectiveness monitoring procedures to evaluate management activities in forested watersheds. We apply a quantitative method to estimate salmonid populations and link these estimates to a set of physical variables used in an assessment of channel condition at the reach scale. We are able to obtain precise estimates of juvenile salmonid populations at the habitat and reach scale; however, we find a lack of strong relationships between channel condition variables and salmonid densities. Nonetheless, a few trends appear, such as relationships between coho salmon and both pools and large wood. A significant and positive relationship exists between coho salmon fry density and two measures of pool frequency. Our results suggest that the response of fish populations to changes in the amount and quality of habitat can be measured by using the tested procedures. Complexity in habitat use, seasonal effects, and external factors tend to mask close relationships between fish populations and physical variables. We also discuss the implications for trophic status for fish populations and how this information may provide a more robust evaluation of land management activities on the aquatic biota in managed watersheds.

- 32 - Buijse A. D.; Coops H.; Staras M.; Jans L. H.; Van Geest G. J.; Grift R. E.; Ibelings B. W.; Oosterberg W. & Roozen F. C. J. M., 2002. Restoration strategies for river floodplains along large lowland rivers in Europe. Freshwater Biology, 47(4) : 889-907.

Keywords: biodiversity • Danube • flood pulse • Rhine • secondary channel

Abstract :

1. Most temperate rivers are heavily regulated and characterised by incised channels, aggradated floodplains and modified hydroperiods. As a consequence, former extensive aquatic/terrestrial transition zones lack most of their basic ecological functions.
2. Along large rivers in Europe and North America, various floodplain restoration or rehabilitation projects have been planned or realised in recent years. However, restoration ecology is still in its infancy and the literature pertinent to river restoration is rather fragmented. (Semi-) aquatic components of floodplains, including secondary channels, disconnected and temporary waters as well as marshes, have received little attention, despite their significant contribution to biological diversity.
3. Many rehabilitation projects were planned or realised without prior knowledge of their potential for success or failure, although, these projects greatly contributed to our present understanding of river-floodplain systems.
4. River rehabilitation benefits from a consideration of river ecosystem concepts in quantitative terms, comparison with reference conditions, historical or others, and the establishment of interdisciplinary partnerships.
5. We present examples from two large European rivers, the Danube and the Rhine, in which the role of aquatic connectivity has been extensively studied. The Danube delta with its diversity of floodplain lakes across an immense transversal gradient (up to 10 km) serves as a reference system for restoration projects along lowland sections of large rivers such as the Rhine in the Netherlands.

- 33 - Burgess S.A. & Bider J.R., 1980. Effects of Stream Habitat Improvements on Invertebrates, Trout Populations, and Mink Activity. The Journal of Wildlife Management, 44(4) : 871-880.

Abstract : Two years of data were studied to determine the effect of increasing the brook trout (*Salvelinus fontinalis*) biomass in a section of stream on mink (*Mustela vison*) activity in the area. The study area consisted of 2 homogeneous sections of stream, one of which served as a control. The other section was improved by physically altering stream habitat. Habitat improvement resulted in trout

population and biomass increases of 208% and 179%, respectively, after 2 years. Crayfish (*Cambarus bartoni*) biomass was 220% greater in the improved section. Mink activity, as determined by a modified sand-transect technique, averaged 52.5% higher in the area surrounding the improved section. However, mink did not respond to the trout biomass increases, nor was mink activity correlated with the activity patterns of any terrestrial prey species. Analysis of mink scats revealed that trout was not an important prey species, whereas crayfish occurred in 20% of all scats found, and in 50% of those from the study area. Thus, habitat improvement and the resulting increases in crayfish production resulted in greater use of that area by mink, but the trout biomass, which increased due to greater available space, mean section depth, and available cover, did not appear to be exploited by the local mink population.

- 34 - Cardinale B.J., Palmer M.A., Swan C.M., Brooks S. & LeRoy Poff N., 2002. The Influence of Substrate Heterogeneity on Biofilm Metabolism in a Stream Ecosystem. Ecology, 83(2) : 412-422.

Abstract : Simplification of natural habitats is a growing global concern demanding that ecologists better understand how habitat heterogeneity influences the structure and functioning of ecosystems. While there is extensive evidence that physical habitat heterogeneity affects the structure of biotic communities (i.e., organismal abundance, distribution, diversity, etc.), ecologists know little about how variability in physical conditions within habitats regulates ecological processes that are important for the functioning of an ecosystem. We performed a field experiment to assess the effects of geomorphic heterogeneity (i.e., variation in substrate size) on rates of benthic productivity and respiration at the scale of whole riffle habitats in a stream ecosystem. While holding median sizes constant, we manipulated variation in the size of stream bed sediments in replicate riffles to create two treatments representing increased and decreased levels of physical habitat heterogeneity relative to natural conditions in the stream. Physical habitat heterogeneity had an immediate and significant impact on the primary productivity of stream algae and on the respiration of the benthic biofilm. The rates of both ecological processes were elevated in the high-heterogeneity riffles, probably as a result of quantified alterations to near-bed flow velocity and turbulence intensity. Results presented here provide support for the widely held, but largely untested, assumption that physical habitat heterogeneity exhibits control over ecosystem-level processes, and it suggests that human-induced simplification of habitats may indeed be altering the functioning of ecosystems.

- 35 - Carlson L.D. & Quinn M.S., 2005. Evaluating the Effectiveness of Instream Habitat Structures for Overwintering Stream Salmonids: A Test of Underwater Video. North American Journal of Fisheries Management, 25(1) : 130-137.

Abstract : Instream habitat structures are often employed by fisheries managers to enhance habitat quality. The effectiveness of instream habitat structures, however, is hindered by a lack of critical and systematic assessment of their success, especially in winter conditions. This study tested the use of underwater video as a method to evaluate the use of instream habitat structures (V-weirs) by overwintering salmonids in the Crowsnest River of southwestern Alberta, Canada. The use of readily available and relatively inexpensive video equipment was shown to be effective in documenting salmonid use of winter habitat both under the ice and in open water. This technique may be particularly appropriate in areas where sampling mortality is a concern and where other methods are impractical or dangerous (e.g., small, ice-covered streams or rivers).

- 36 - Caruso B.S., 2006. Effectiveness of braided, gravel-bed river restoration in the Upper Waitaki Basin, New Zealand. River research and applications, 22(8) : 905-922.

Keywords : stream • aquatic environment • Oceania • freshwater environment • gravel bed • rivers • wetland • New Zealand • ecological recovery ;

Abstract : In 1991 the New Zealand Department of Conservation implemented Project River Recovery (PRR) to restore braided, gravel-bed riverine and wetland habitats in the Upper Waitaki Basin on the South Island. These are critical habitats for wading and shore birds, including threatened species, but have been degraded by hydroelectric power development. This paper evaluates the

effectiveness of PRR after more than 10 years with regard to key issues, effective methods, and lessons learned. Few restoration programs explicitly include evaluation of effectiveness or criteria for success, thereby limiting knowledge transfer and benefits to new or ongoing projects. This evaluation is based on site visits, interviews with program staff, review of PRR documents, comparisons with international restoration programs and recommendations, and a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis. Primary components include pest plant and animal control, wetland construction and enhancement, research and monitoring, and public awareness. The program has elements common to many other restoration programs, including strategic planning and annual reporting. Its strengths include well-defined goals, stakeholder collaboration, and successful integration of science with restoration as part of adaptive management. PRR could benefit from improved understanding of physical and watershed characteristics, expansion of goals at multiple scales, additional collaboration with other organizations, and knowledge transfer. Threats include weed invasions and increased recreational and land-use impacts.

- 37 - Cederholm C.J., Bilby R.E., Bisson P.A., Bumstead T.W., Fransen B.R., Scarlett W.J. & Ward J.W., 1997. Response of Juvenile Coho Salmon and Steelhead to Placement of Large Woody Debris in a Coastal Washington Stream. North American Journal of Fisheries Management, 17(4) : 947-963.

Abstract : Many fish habitats have been altered in Pacific Northwest streams and rivers over the past century by a variety of land use practices, including forestry, urbanization, agriculture, and channelization. There are research and management needs for evaluation of the effectiveness of rehabilitation projects intended to enhance stream fish habitat recovery. The response of populations of juvenile coho salmon *Oncorhynchus kisutch* and steelhead *O. mykiss* to addition of large woody debris (LWD) was tested in North Fork Porter Creek (NFPC), a small coastal tributary of the Chehalis River, Washington. The NFPC was divided into three 500-m study sections; two sections were altered with two approaches (engineered and logger's choice) to adding LWD, and the third was kept as a reference site. Immediately after LWD addition, the abundance of LWD pieces was 7.9 times greater than the pretreatment level in the engineered site and 2.7 times greater in the logger's choice site; abundance was unchanged in the reference site. Subsequent winter storms brought additional LWD into all three study sites. In the years that followed, the amount of pool surface area increased significantly in both the engineered and logger's choice sites, while it decreased slightly in the reference site. After LWD addition, winter populations of juvenile coho salmon increased significantly in the engineered and logger's choice sites, while they remained the same in the reference site. There were no significant differences in the coho salmon populations during spring and autumn within the reference, engineered, or logger's choice sites. The coho salmon smolt yield from the engineered and logger's choice sites also increased significantly after LWD addition, while it decreased slightly in the reference site. After LWD addition, the reference site and the engineered site both exhibited increases in age-0 steelhead populations; however, the population in the logger's choice site did not change. There was no difference in age-1 steelhead abundance among sites, or before and after enhancement during any season. Winter populations of juvenile coho salmon and age-0 steelhead were related inversely to maximum and mean winter discharge.

- 38 - Champoux O., Biron P.M. & Roy A.G., 2003. The Long-Term Effectiveness of Fish Habitat Restoration Practices: Lawrence Creek, Wisconsin. Annals of the Association of American Geographers, 93 (1) : 42–54.

Abstract : Although many streams in North America have been rehabilitated to improve the habitat of salmonids, little is known about the long-term impacts of such practices on salmonid habitats and on river dynamics. The success of these improvement schemes is often assessed a short time after the work is completed and is usually based on changes in the targeted biological populations. This article examines the long-term effects of bank-cover deflectors on the physical fish habitat and on the channel morphology. The study was conducted on Lawrence Creek, a small stream in Wisconsin, where trout habitat had been affected negatively by intense cattle grazing. Data on the physical habitat and on channel morphology were collected on a 600-m-long reach in 1963 (immediately prior to the rehabilitation work), in 1966, and in 1999. In the upstream section, the channel flows through a moraine deposit where bed material is coarser than the material of the outwash plain found in the downstream portion of the reach. Results indicate that fish habitat in 1999 was better than in 1963 but

has deteriorated substantially since 1966. Pool area increased from 267 m^2 to 625 m^2 between 1963 and 1966, but has decreased to 488 m^2 since then. Most of this deterioration, however, is concentrated in the morainic section. In the outwash plain, the deflectors are still in good condition, and the area occupied by pools has remained constant since 1966. In the morainic section, most structures are no longer efficient and the channel is unstable due to high bed-shear stress values, which entrain bed and bank erosion. Effective long-term rehabilitation schemes should therefore carefully consider the varying sensitivity of river reaches due to different geomorphic contexts.

- 39 - Chapman D.W., 1995. Efficacy of structural manipulations of instream habitat in the Columbia River basin. Rivers, 5(4) : 279-293.

Abstract : Instream habitat structures designed to enhance salmon populations have been placed in many tributaries in the Columbia River basin. Examination of test data reveals little reliable evidence of benefits. Suitable protocols for study require many years and suitably paired test and reference areas; a commitment of resources not evident to date. Emphasis on instream structures reduces emphasis on problems that contribute to loss of instream habitat quality. I suggest that managers shift attention to watershed husbandry instead of relying on instream palliatives.

- 40 - Clarke S.J. & Wharton G., 2000. An investigation of marginal habitat and macrophyte community enhancement on the River Torne, UK. Regulated Rivers: Research & Management, 16(3) : 225-244.

Keywords : macrophytes • marginal habitat • river enhancement • River Torne

Abstract : During floodbank raising work as part of a major capital flood defence scheme on the River Torne between 1985 and 1990, selected reaches of the main trapezoidal channel were enhanced. By winning spoil from the channel margins and from borrow pits in the floodplain, a more varied marginal zone was created which maximised the potential habitat for wetland plant communities and their associated fauna. Enhancement comprised bank re-profiling to create narrow wetland shelves (berms), shallow bays, channel margins of varying shape and depth and linear still ponds from the borrow pits. The 1990 planting programme comprised 11 macrophyte species and a total of 7740 individual plants. This paper reports on an initial study to evaluate the marginal habitat enhancements on the River Torne 5 years after completion of the project. Lack of pre-scheme data necessitated a space-time substitution; enhanced river margins were compared with neighbouring reaches that had undergone conventional floodbank repair and remained as trapezoidal channel sections planted with a standard, low maintenance seed mix. Marginal vegetation was surveyed and supported by measurements of the physical habitat at 10 enhanced and 10 conventionally-engineered reaches. The macrophyte surveys and the results from the cluster analysis and polar ordination indicate that enhanced and conventionally-engineered reaches are floristically distinct and that the enhanced reaches have a more varied macrophyte community. The results from the Mann-Whitney U-tests show that enhanced reaches have significantly higher values of wetland species diversity and equitability, percentage of wetland species, bank width and soil moisture and significantly lower bank angles. However, the correlation and linear regression analyses did not show any strong associations between the physical habitat and plant parameters.

- 41 - Clarke S.J., Bruce-Burgess L., Wharton G., 2003. Linking form and function: towards an eco-hydromorphic approach to sustainable river restoration. Aquatic Conservation: Marine and Freshwater Ecosystems, 13(5) : 439-450.

Keywords : river restoration • geomorphology • ecohydrology.

Abstract :

1- River restoration is now widely undertaken and may be considered an increasingly important aspect of river management. Recent developments in European legislation (Habitats Directive and the Water Framework Directive) should give further impetus to river restoration across EU member states, as this legislation places greater emphasis on the processes that support river ecology.

2- Traditional river restoration approaches have been reach-focused and opportunistic, capitalizing on flood defence works and the cooperation of sympathetic landowners.
3- Furthermore, many schemes have been species- or habitat-driven and, thus, have sought to recreate channel forms believed to be favoured by particular species or associated with particular habitats. Such approaches have not always given due attention to the underlying geomorphological processes that create channel form and, consequently, the schemes have not been self-sustaining, requiring continued management input.
4- Consistent with the ethos of the Water Framework Directive, an eco-hydromorphic approach to river restoration is proposed here. This approach views spatial and temporal heterogeneity as fundamental characteristics of fluvial systems and advocates recreating a *framework* within which natural processes, such as sediment transport and nutrient dynamics, can occur.
5- Mesoscale habitat approaches are considered as one possible way to plan and achieve this framework, providing the potential to link the wide range of spatial and temporal scales that characterize river systems.
6- It is argued that river restoration will only be sustainable if it is undertaken within a process-driven and strategic framework with inputs from a wide range of specialists. Such an approach needs to be reviewed constantly in light of appraisal and monitoring of previous river restoration schemes.

- 42 - Cooper, C.M., Testa III S. & Shields Jr. F.D., 2004. Rehabilitation of a severely damaged stream channel with large woody debris structures: Macroinvertebrate community response. North American Benthological Society Bulletin, 21(1):360.

Abstract : Although woody debris addition has been widely employed for salmonid habitat rehabilitation, reports describing treatment of incised, sand-bed streams have been rare. Studies were conducted at a fourth-order stream in north-central Mississippi where aquatic habitat conditions were marked by extremely shallow flow and sand-dominated substrates. Seventy-two large woody debris structures (LWDS) were placed within the study channel. Macroinvertebrates in five stream reaches were collected from large woody debris, leaf packs / coarse particulate organic matter, streambed sand substrate, and supplemented with a qualitative multi-habitat sample during three seasons before and three seasons following stream treatment with LWDS. Overall, numbers of individuals were very similar following rehabilitation efforts. A total of 149 macroinvertebrate taxa were identified, with 91 taxa observed before treatment and 118 taxa observed following treatment, and the number of shared taxa was only 60. Jaccard and Sorenson incidence-based similarity indices both indicated a large change from before to after treatment. The Shannon index and Fisher's log series alpha index indicated low overall diversity before treatment and much higher diversity after treatment. Overall sample evenness also increased substantially in collections after treatment. Despite many LWDS failures, several positive macroinvertebrate community responses to rehabilitation efforts were observed.

- 43 - Cooperman M.S., Hinch S.G., Bennett S., Branton M.A., Galbraith R.V., Quigley J.T. & Heise B.A.; 2007. Streambank restoration effectiveness : Lessons learned from a comparative study. Fisheries (American fisheries Society), 32 (6) : 278-291.

Abstract : Post-treatment effectiveness monitoring should be an integral part of stream restoration efforts, but it is often neglected due to lack of funds or insufficient project planning. Here we report results of an effectiveness evaluation of a streambank restoration program for salmon streams in the southern interior of British Columbia. Restoration involved treating eroding riverbanks with bank grading, riparian plantings, and installation of rock toes, rock-wood current deflectors, and livestock exclusion fencing. Absence of pre-treatment site characterization data necessitated comparing post treatment conditions at treated sites to conditions at untreated eroding control sites. We measured in-channel and riparian conditions plus invertebrate abundance and biomass at 16 sites treated between 1997 and 2002 and 11 nearby control sites. Treatment and control sites did not substantively differ in their habitat condition or aquatic macroinvertebrate abundances, although treated sites tended to have more shrubs along the outside bank, higher inside banks, and narrower wetted widths. Absence of statistical differences between treatment and control sites might be due to low statistical power, as >50 sites per group would need to be sampled for power to reach 0.8 at the effect sizes observed. Site specific channel gradient, a variable unaffected by restoration actions, was correlated with many of the variables we measured to characterize habitat condition, thereby confounding our ability to determine the magnitude of change relating to treatment efforts. Our results demonstrate the weaknesses of

relying on a post-treatment, between-group comparison experimental design for restoration effectiveness monitoring. We suggest collection of pre-treatment data should be an essential part of the restoration process so more appropriate "before-after" experimental designs can be applied.

- 44 - Cowx I.G. & Van Zyll de Jong, 2004. Rehabilitation of freshwater fisheries: tales of the unexpected? Fisheries Management and Ecology, 11(3-4) : 243-249.

Abstract : The maintenance and development of freshwater fisheries is based on an understanding of the many biotic and abiotic factors influencing the fish population dynamics. This information has been used to derive models on the most suitable habitats for different fish species and predict carrying capacities of the water bodies concerned. They are also used to determine the impact of various anthropogenic activities on the fish stocks and the possible outcome of enhancement and rehabilitation activities. Unfortunately, rehabilitation schemes based on such a narrow approach are not always as effective as predicted. This is because the schemes have failed to address the wider catchment problems affecting the fish communities. This paper presents two case studies to illustrate this point, and suggests that strategic management is required to improve the success of future rehabilitation schemes.

- 45 - Crispin V., House R. & Roberts D., 1993. Changes in Instream Habitat, Large Woody Debris, and Salmon Habitat after the Restructuring of a Coastal Oregon Stream. North American Journal of Fisheries Management, 13(1) : 96-102.

Abstract : Elk Creek, a drainage of 26.6 km^2 that historically has been severely degraded by logging, floods, and stream cleaning, was restructured in 1986, 1987, and 1989. In all, 106 full-spanning and 94 partial-spanning structures were installed along 4.2 km of stream. An upstream reach of 0.5 km was left untreated. Inventories of stream habitat conditions and large woody debris conducted in 1985 and 1990 (i.e., before and after restructuring), showed that restructuring caused substantial changes favoring suitable habitat for coho salmon *Oncorhynchus kisutch*; meanwhile, the untreated reach became less favorable for rearing coho salmon. Stream surface area and water volume, respectively, increased 74 and 168% in the treated reach, and 8 and 37% in the untreated reach. Surface area of pool and suitable of channel habitat, the most important summer and winter rearing components for coho salmon juveniles, increased nearly fivefold in the treated reach at summer low flow. In the treated reach, which had a mature riparian area, newly recruited large woody debris was 52% greater in mean length and 60% greater in mean diameter than in the untreated reach, which had a previously logged riparian area. Whereas in the treated reach suitable summer habitat for coho salmon increased fivefold and suitable winter habitat increased sixfold, in the untreated reach suitable summer habitat decreased by half and no winter habitat was available.

- 46 - Davis N.M., Weaver V., Parks K. & Lydy M.J., 2003. An Assessment of Water Quality, Physical Habitat, and Biological Integrity of an Urban Stream in Wichita, Kansas, Prior to Restoration Improvements (Phase I). Archives of Environmental Contamination and Toxicology, 44(3) : 351-359.

Abstract : Urban development alters the natural hydrological conditions of many streams and rivers often resulting in the degradation of water quality, physical habitat, and biotic integrity of lotic systems. Restoration projects attempt to improve and maintain the ecological integrity of urban streams; however, few projects have quantified improvements to stream ecology following implementation of restoration measures. This paper summarizes pre-restoration data collected as part of an urban stream restoration project on Gypsum Creek in Wichita, Kansas. Water quality monitoring revealed eutrophic conditions in the stream and the presence of pesticides. Channelization has led to changes in physical habitat including bank erosion, sedimentation, loss of substrate and channel diversity, elimination of in-stream aquatic habitat, removal of riparian vegetation, and decreased base flows. Benthic macroinvertebrate communities appear degraded with more than 90% of individuals collected described as tolerant to anthropogenic stressors. Fish communities were assessed with an Index of Biotic Integrity and were rated as poor to fair, with trophic structure dominated by generalists, no sensitive species present, and one-third of the species collected considered non-native. Overall, the data collected strongly suggest that site-specific restoration measures need to be implemented in

order to improve and maintain the ecological condition of Gypsum Creek. Recommendations for improvements have been made to city managers, with implementation beginning in spring 2003 (dependent upon funding availability).

- 47 - Dolinsek J., Grant J.W.A., Biron P.M., 2007. The effect of habitat heterogeneity on the population density of juvenile Atlantic salmon *Salmo salar* L. Journal of Fish Biology, 70(1) : 206–214.

Abstract : In each of eight sites in 2 years in Catamaran Brook and the Little Southwest Miramichi River, in New Brunswick, Canada, 36 boulders (median diameter = 0·20 m) were added to a 2 × 3 m quadrat in one treatment, all boulders were removed in another treatment, and one quadrat was left as a control. As predicted, adding boulders increased the density of salmonid fishes, primarily juvenile Atlantic salmon *Salmo salar*, by 2·8-fold, but had no significant effect on non-territorial fishes, primarily cyprinids and catostomids. Moreover, the effect of adding boulders was greatest for age 0+ year Atlantic salmon, intermediate for age 1+ year Atlantic salmon and had no effect on age 2+ year Atlantic salmon. The results suggest that adding boulders is an effective short-term technique for increasing the density of stream-dwelling salmonids.

- 48 - Ebrahimnezhad M. & Harper D.M., 1998. The biological effectiveness of artificial riffles in river rehabilitation. Aquatic Conservation: Marine and Freshwater Ecosystems, 7(3) : 187-197.

Abstract :

1- The biological effectiveness of a series of artificial riffles constructed from cobble-sized local material in the channelized Harper's Brook (Northamptonshire, England) was measured by comparing the macroinvertebrate communities of three new riffles with a control natural riffle upstream, and with three original channelized stretches (runs).
2- The mean diversity of macroinvertebrates in the seven sites was significantly different: diversities of the natural riffle and two shallower artificial riffles were highest, whilst those of the other deeper, artificial riffle and the three channelized runs were lowest.
3- There was significant negative correlation between diversity and depth; significant positive correlation between diversity and velocity.
4- Artificial riffles, if correctly constructed, do improve the habitats and increase biodiversity of macroinvertebrates to levels similar to a natural riffle. A minimum velocity of 40 cm s^{-1} and maximum depth of 25 cm is necessary during low-flow discharges for artificial riffles to function biologically as natural riffles.

- 49 - England J., Skinner K.S. & Carter M.G., 2007. Monitoring, river restoration and the Water Framework Directive. Water and Environment Journal, OnelineEarly Article.

Abstract : Monitoring is an important aspect of any procedure that seeks to determine whether a technique has worked effectively. The river restoration process is no different. Unfortunately, monitoring is often not undertaken due to constraints on time and resources, as well as the commonly held belief that river restoration is inherently a good thing and, as a result, monitoring is unnecessary. There are many reasons to monitor projects and among the most important is the need to learn from experiences and for regulatory compliance. This paper examines the issues associated with the monitoring of river restoration schemes. In particular, it details monitoring selection models focusing on those associated with ecology and geomorphology. The paper also considers the requirements of monitoring schemes that will help deliver the goals of the Water Framework Directive (WFD).

- 50 - Fausch K.D., Gowan C., Richmond D. & Riley S.C., 1994. The role of dispersal in trout population response to habitat formed by large woody debris in Colorado mountain streams. Bulletin français de la pêche et de la pisciculture , 68(337/339) : 179-190.

Keywords : choix habitat • aménagement hydraulique • barrage • déchet végétal • bassin élevage • cours eau • montagne • abondance écologique • migration animale • Colorado • Salmonidae • Etats Unis • Amérique du Nord • Amérique • milieu eau douce • gestion population • Pisces • Vertebrata.

Abstract : Un peu partout dans le monde, les aménagistes des pêches utilisent souvent des rondins pour réaliser des mouilles pour les salmonidés, souvent pour compenser l'absence de grands débris ligneux (LWD) due à la déforestation ou à d'autres perturbations des forêts alluviales. Des mesures des LWD réalisées sur 11 ruisseaux de montagne du Colorado drainant de vieilles forêts de résineux (*Picea - Abies*) montrent qu'ils sont à l'origine de la plupart des mouilles. Les morceaux qui contribuent à la formation des mouilles sont, en moyenne, plus grands que ceux qui n'en forment pas. La plupart enjambe le chenal perpendiculairement à l'écoulement et forme des mouilles de chute («plunge pool») et des mouilles de retenue («dammed pool»). Les aménagistes des pêches qui utilisent des troncs perpendiculaires à l'écoulement pour réaliser des mouilles considèrent généralement que cette addition d'habitat améliore la survie des salmonidés résidents pendant les périodes critiques comme l'hiver. Une expérience de longue durée, réalisée pour tester cette hypothèse dans six ruisseaux de montagne du Colorado, a montré que les populations de truites résidentes augmentaient rapidement et significativement dans des portions expérimentales de 250m, par rapport à des témoins adjacents. Cependant, des mesures de la dispersion réalisées par des piégeages et des recaptures de truites marquées ont montré que les mouilles formées par des troncs augmentent les populations de truites adultes en permettant aux truites qui étaient en phase de déplacement de rester dans les portions expérimentales plutôt qu'en améliorant la survie hivernale sur place, comme le décrivent d'autres auteurs. La recherche sur les salmonidés d'eau courante non migrateurs et leur gestion a jusqu'à présent été marquée par un modèle impliquant des déplacements limités, ce qui implique que les adultes soient relativement sédentaires. Cependant, l'analyse d'études antérieures sur les déplacements démontre que la plupart des expérimentateurs ne s'intéressent qu'aux poissons recapturés dans les portions où ils ont été relâchés, ce qui est critiquable si l'on souhaite mettre des mouvements en évidence. Le fait que les poissons présentent des déplacements conséquents a des implications importantes pour l'amélioration et la restauration de l'habitat, et plaide pour une gestion prenant en compte le bassin versant.

- 51 - Feist B.E., Steel E.A., Pess G.R. & Bilby R.E., 2003. The influence of scale on salmon habitat restoration priorities. Animal Conservation, 6 : 271-282.

Abstract : Habitat loss and alteration is the leading cause of species' declines world-wide, therefore habitat restoration and protection is a prominent conservation strategy. Despite obvious connections between habitat and threatened or endangered species, conservationists have been hard pressed explicitly to link abundance or population health with habitat attributes. Given that habitat relationships with species are often characterized at a spatial scale that does not account for the functional relationships between habitat and populations, it is not surprising that the habitat-population conundrum persists. In order to explore the influence of spatial scale on the apparent relationship between habitat and populations, we examined the relationship between GIS-based habitat data and spring/summer chinook salmon (*Oncorhynchus tshawytscha*) redd (spawning nests built by females) densities in the Salmon River basin, Idaho, at two very different spatial scales: stream reach and watershed. Redd density was strongly correlated with climate, geology, wetlands and terrain. However, our stream-reach scale models provided poor predictive power compared with the watershed scale models. Based on these results, we conclude that our perception of which habitat attributes were important was clearly a function of our scale of observation, and that restoration efforts should focus on conditions at the watershed or landscape scale when attempting to do local or reach scale restoration projects.

- 52 - Finstad A.G., Einum S., Forseth T. & Ugedal O., 2007. Shelter availability affects behaviour, size-dependent and mean growth of juvenile Atlantic salmon. Freshwater Biology, 52(9) : 1710–1718.

Abstract :

1- Anthropogenic disturbances of the physical habitat and corresponding effects on fish performance are key issues in stream conservation and restoration. Reduced habitat complexity because of increased sediment loadings and canalization is of particular importance, but it is not clear to what extent fish populations are influenced directly by changes in the physical environment, or indirectly through changes in the biotic environment affecting the food availability.

2- Here, we test for the direct effect of habitat complexity on the performance (growth) of juvenile Atlantic salmon by manipulating shelter availability (interstitial spaces in the substrate) across 20 semi-natural stream channels without altering the substrate composition, and stocking each channel with a common density of fish. A simple method for measuring salmonid shelters using flexible PVC tubes was developed and tested. Daytime sheltering behaviour and growth rates were compared across the channels differing in shelter availability.

3- Measured shelter availability was strongly negatively correlated with observed number of fish not finding shelters and mass loss rates of the fish (growth performance) increased with decreasing number of measured shelters. Number and mean depth of interstitial spaces explained up to 68% and 24% of the among-channel variation in sheltering behaviour and growth performance, respectively. Furthermore, negative effects of shelter reduction increased with fish body size. Thus, changes in habitat structure may even influence the size selection gradients.

4- Shelter availability is an easily measured variable, possibly affecting the population demographics and long-term evolutionary processes, and is therefore a key habitat factor to be considered in stream restoration and habitat classification.

- 53 - Follstad Shah J., Dahm C.N., Gloss S.P. & Bernhardt E.S., 2007. River and Riparian Restoration in the Southwest: Results of the National River Restoration Science Synthesis Project. Restoration Ecology, 15(3) : 550–562.

Abstract : Restoration activity has exponentially increased across the Southwest since 1990. Over 37,000 records were compiled into the National River Restoration Science Synthesis (NRRSS) database to summarize restoration trends and assess project effectiveness. We analyzed data from 576 restoration projects in the Southwest (NRRSS-SW). More than 50% of projects were less than or equal to 3 km in length. The most common restoration project intent categories were riparian management, water quality management, in-stream habitat improvement, and flow modification. Common project activities were well matched to goals. Conservative estimates of total restoration costs exceeded $500 million. Most restoration dollars have been allocated to flow modification and water quality management. Monitoring was linked to 28% of projects across the Southwest, as opposed to just 10% nationwide. Mean costs were statistically similar whether or not projects were monitored. Results from 48 telephone interviews provided validation of NRRSS-SW database analyses but showed that project costs are often underreported within existing datasets. The majority of interviewees considered their projects to be successful, most often based upon observed improvements to biota or positive public reaction rather than evaluation of field data. The efficacy of restoration is difficult to ascertain given the dearth of information contained within most datasets. There is a great need for regional entities that not only track information on project implementation but also maintain and analyze monitoring data associated with restoration. Agencies that fund or regulate restoration should reward projects that emphasize monitoring and evaluation as much as project implementation.

- 54 - Friberg N., Kronvang B., Svendsen L.M., Hansen H.O. & Nielsen M.B., 1994. Restoration of a channelized reach of the River Gelså, Denmark: Effects on the macroinvertebrate community. Aquatic Conservation: Marine and Freshwater Ecosystems, 4(4) : 289 – 296.

Abstract : The restoration of a 1.3 km straightened and channelized reach of the River Gelså to a new 1.9 km meandering course is one of the largest river restoration projects so far undertaken in Denmark. In order to elucidate the ecological impact of restoration, the macroinvertebrate community

present in the reach prior to and following its restoration was compared with that in an upstream reach that remained straight and channelized.
Two years after restoration of a meandering course, macroinvertebrate density and diversity was greater than in the upstream control reach, *Gammarus pulex* L. being particularly abundant in the restored reach. In general, species preferring a stony habitat seemed to favour the new reach; *Heptagenia sulphurea* Müll. was only found on stones in the restored reach, and was totally absent from the control reach. Two other stone-preferring species, *Ancylus fluviatilis* Müller and *Hydropsyche pellucidula* Curtis, were found in higher density in the control reach; however, this probably reflects competition for the limited space available on stones.
The study shows that river restoration can have a positive impact on macroinvertebrate community structure, and probably higher trophic levels also, such as fish, due to increased numbers of potential prey organisms. In addition, the study suggests that the impact of restoration projects on the macroinvertebrate community is best understood by undertaking both qualitative and quantitative studies.

- 55 - Friberg N., Kronvang B., Hansen H.O.& Svendsen L.M., 1998. Long-term, habitat-specific response of a macroinvertebrate community to river restoration. Aquatic Conservation: Marine and Freshwater Ecosystems, 8(1) : 87-99.

Abstract : In 1989 a 1.3 km channelized reach of the River Gelsaa was restored to a new 1.9 km meandering course. The restored reach was subsequently (1989-95) monitored for changes in physical and biological features compared with an upstream channelized reach. Weed clearance and other types of maintenance practices have not been undertaken in either reach since 1990. By 1993 the restored reach had already stabilized, both physically and with respect to diversity and density of the macroinvertebrate community. The upstream reach gradually improved physically during the study period, but remained less heterogeneous than the restored reach, with only a very limited amount of stony substrate. Stone-dwelling macroinvertebrate species were consequently still scarce in 1995, while overall diversity and density of the macroinvertebrate community was similar to that in the restored reach. The results indicate that natural rehabilitation of physical features is a rather fast process, but in some ways cannot match the almost instantaneous heterogeneity obtained by active restoration measures.

- 56 - Frissell C.A. & Nawa R.K., 1992. Incidence and Causes of Physical Failure of Artificial Habitat Structures in Streams of Western Oregon and Washington. North American Journal of Fisheries Management, 12(1) : 182-197.

Abstract : In recent years an increasing share of fishery management resources has been committed to alteration of fish habitat with artificial stream structures. We evaluated rates and causes of physical impairment or failure for 161 fish habitat structures in 15 streams in southwest Oregon and southwest Washington, following a flood of a magnitude that recurs every 2–10 years. The incidence of functional impairment and outright failure varied widely among streams; the median failure rate was 18.5% and the median damage rate (impairment plus failure) was 60%. Modes of failure were diverse and bore no simple relationship to structure design. Damage was frequent in low-gradient stream segments and widespread in streams with signs of recent watershed disturbance, high sediment loads, and unstable channels. Comparison of estimated 5–10-year damage rates from 46 projects throughout western Oregon and southwest Washington showed high but variable rates (median, 14%; range, 0–100%) in regions where peak discharge at 10-year recurrence intervals has exceeded 1.0 $m^3.s^{-1}.km^{-2}$. Results suggest that commonly prescribed structural modifications often are inappropriate and counterproductive in streams with high or elevated sediment loads, high peak flows, or highly erodible bank materials. Restoration of fourth-order and larger alluvial valley streams, which have the greatest potential for fish production in the Pacific Northwest, will require reestablishment of natural watershed and riparian processes over the long term.

- 57 - Fuchs U. & Statzner B., 2006. Time scales for the recovery potential of river communities after restoration: Lessons to be learned from smaller streams. Regulated Rivers: Research & Management, 5(1) : 77-87.

Keywords : lotic ecosystems • restoration • isolation • recovery • inoculum • benthic macroinvertebrates • Central Europe.

Abstract : German politicians have promised that the River Rhine will be sufficiently restored within twelve years to permit salmon to live there again. Obviously the large rivers in Central Europe are more isolated from each other than smaller streams, and communities donating potential colonizers (if they exist at all) are further apart for possibly restored large rivers than for smaller streams. Thus, recovery can be expected to be faster in small streams than in big rivers after restoration (or reduction of detrimental human influence). Therefore, two restoration projects in German lowland streams, which differ in their degree of isolation, can serve as an indicator to the time periods which could *at least* be expected for the recovery of Central European rivers.
Under optimal conditions (almost completely intact communities upstream and downstream of a 400 m restored reach) in North Germany, sufficient recovery of benthic macroinvertebrate fauna could be achieved in relatively short periods. However, in a rather isolated stream reach in the Upper Rhine valley (closest intact lotic ecosystems of a comparable type were found 20-25 km away) a sufficient recovery of benthic macroinvertebrate fauna was not achieved within five years after restoration, although there was high diversity of physical habitats and the water quality was acceptable (except for two oil accidents in the fourth and the fifth year).
Hence, we conclude that recovery of a large Central European river ecosystem like the Rhine, which has lost a large number of its former species and is more isolated than small streams, will require more than twelve years to reach a state significantly different from the present one.

- 58 - García de Jalón D. & Gortázar J., 2007. Evaluation of instream habitat enhancement options using fish habitat simulations: case-studies in the river Pas (Spain). Aquatic Ecology, 41(3) : 461-474.

Keywords : Atlantic salmon (*Salmo salar* L.) • Frequency Weighted Habitat (FWH) • habitat simulation • Instream Flow Incremental Methodology (IFIM) • instream habitat enhancement • River2D • Weighted Useable Area (WUA).

Abstract : In the northern coast of Spain there are rivers with Atlantic salmon populations. In the upper reaches of one of these streams, river Pas, the effectiveness of habitat enhancement measures was evaluated, under different instream flow conditions. By means of the Instream Flow Incremental Methodology and using a two dimensional hydraulic model (River2D, Steffler P (2000) *Software River2D. Two Dimensional Depth Averaged Finite Element Hydrodynamic Model*. University of Alberta, Canada), the potential value of stream habitat for different salmon development stages requirements was measured by Weighted Useable Area (WUA). This habitat evaluation was carried out for the unmodified stream reach, which represent the control or natural conditions. Habitat improvement measures (alternate deflectors and low dams) were simulated in the original riverbed topography. Over this modified base, habitat was estimated running River2D again. By comparing the salmon habitat evaluations in the control conditions with those obtained under those improvement conditions we have been able to assess the effectiveness of each one, and the instream flow environment at which maximum improvement is reached. The maximum habitat improvement was obtained around 10 m^3/s for the adult salmon, and for the fry and parr it was around 6 m^3/s. However, the habitat simulation results show that with both improvement measures, under a natural flow regime the mean annual habitat increases around 1% of the WUA in relation to the control conditions, which is not a significant improvement. A similar small WUA increase was obtained when changing the bed topography, considering geomorphological adjustments due to the new erosion and sedimentation areas caused by the presence of these structures. Therefore, these types of habitat improvement measures are not recommended in these stream reaches.

- 59 - Gerhard M. & Reich M., 2000. Restoration of Streams with Large Wood: Effects of Accumulated and Built-in Wood on Channel Morphology, Habitat Diversity and Aquatic Fauna. International Review of Hydrobiology, 85(1) : 123-137.

Keywords : large woody debris • stream restoration • channel morphology • microhabitats • riparian zone.

Abstract : Large wood was added to regulated and straightened reaches of two third-order streams in Central Germany; the Jossklein and the Lüder. In the Jossklein, the wood was a by-product of the forest management in the floodplain and accumulated in the channel during peak floods. In the Lüder, logs were builtin as deflectors in regular intervals and fixed within the stream bank. In the Jossklein, the addition of large wood improved the channel morphology within four years. The variation in channel width and depth was considerably larger than in a regulated section. The extension of the riparian zone, especially of the semi-aquatic gravel and sand bars was strongly correlated with the amount of large wood that accumulated in the single sections. The number of microhabitats and their patchiness on the stream bottom was higher in restored sections, as well as the density of macroinvertebrates and the species number. In the Lüder, some of the observed trends were similar, but not that clear. This differences can be explained by higher amounts of LWD in the Jossklein, organised in dynamic debris dams situated above the water level at low flow, in contrast to the single stacks of logs at the Lüder, situated as stable deflectors within the low flow water level.

- 60 - Gore J.A., 1982. Benthic invertebrate colonization: source distance effects on community composition. Hydrobiologia, 94(2) : 183-193.

Keywords : benthos • colonization • functional groups • foraging habits • feeding preferences • stream restoration.

Abstract : The trends in colonization and establishment of equilibrium benthic communities in a reclaimed coal strip-mined river channel were analyzed for 17 months after channel construction. The MacArthur-Wilson island colonization theories and an analysis of community composition by simultaneous daily comparisons between source and new channel communities were employed. Each downstream site attained an equilibrium condition at approximately twice the time required for a site 200 m closer to the upstream source area of drifting colonizers. When considering functional groups of aquatic invertebrates, the collector-gatherers and collector-filterers of detrital material were the initial colonizers. With respect to foraging habit, those invertebrates which were found commonly in the water column above the substrate, the swimmers and clingers, were found to be the initial colonizers of the most distant substrate islands. As habitat complexity increased, trophic complexity increased with priority of arrival and dispersal potential determined by trophic position and foraging habit. It is suggested that the Jaccard community association analysis be used to assess stable new community conditions. The index provides an indication in changes in diversity and density and can be compared with source area communities to determine simultaneous changes within both communities. Ultimately, the restored channel 'islands' become a continuous extension of the source area habitat. Colonization trends and time to stability are affected by number of pools, tributary streams, and elimination of rare species populations prior to reclamation.

- 61 - Gore J.A.,. Crawford D.J. & Addison D.S., 1998. An analysis of artificial riffles and enhancement of benthic community diversity by physical habitat simulation (PHABSIM) and direct observation. Regulated Rivers: Research & Management, 14(1) : 69-77.

Keywords : restoration • PHABSIM • artificial riffle • hydraulic stream ecology • macroinvertebrates • habitat quality.

Abstract : Critical to river rehabilitation decisions is the prediction of the benefits of certain procedures. In low-order systems, planning should focus on flow requirements of lotic organisms, especially benthic species. We examined the value of placement of artificial riffles in Holly Fork, a low-order tributary of the West Sandy River (west Tennessee). The objective was to determine if the instream flow incremental methodology (IFIM) and its component computer model, PHABSIM, could adequately predict the habitat value of the riffles for benthic macroinvertebrates and if, after

colonization, this "value" was reflected by increased diversity of benthic macroinvertebrates. Holly Fork is a severely head-cut channel with 2 m high vertical embankments and a substrate dominated by sand and fines, with occasional gravel riffles. We chose to conduct the analysis of each stream reach using macroinvertebrate diversity as the "target". Habitat suitability criteria, developed using data from adjacent watersheds, predicted a range of suitable physical conditions that supported highest benthic community diversity. A traditional IFIM analysis of a reach of the Holly Fork indicated that, below 0.2 m^3/s (a flow exceeded 10% of the time), less than 5% of the wetted area contained adequate habitat for benthic macroinvertebrates. At optimum flows (0.4 m^3/s and higher), only 15% of the wetted area, primarily across small gravel bars, was adequate to support high community diversity. Two artificial riffles, composed of large cobble and boulder keystones, with leading and trailing aprons of medium cobble and gravel, were placed at 35 m intervals in the test section. After hydrological stabilization and time for colonization by macroinvertebrates, the artificial riffles were re-analysed. The simulation predicted that this reach contained significantly higher amounts of available benthic habitat at low flows (more than tripled), and over 40% of the total wetted area should support high benthic community diversity at optimal flows. The presence of artificial riffles contributed most of this habitat enhancement. A plot of cell-by-cell composite habitat suitability and sample diversity from these cells revealed a significant correlation between PHABSIM predictions and actual community diversity. This technique can be an aid in demonstrating the value of certain restoration structures during the rehabilitation planning process. Our data suggest that benthic community diversity is an appropriate target for evaluation of instream flow values that sustain ecosystem integrity.

- 62 - Gørtz P., 1998. Effects of stream restoration on the macroinvertebrate community in the River Esrom, Denmark. Aquatic Conservation: Marine and Freshwater Ecosystems, 8(1) : 115-130.

Keywords : stream restoration • effect-evaluation • quantitative and semi-quantitative bio-monitoring • bootstrapping • macroinvertebrate community • fish population.

Abstract :

1. The macroinvertebrate fauna of three restored and two reference sections in the River Esrom was compared 4 years after completion of a restoration project using gravel, boulders and stream concentrators on a 3.2-km reach in order to enhance the physical structure and natural trout spawning.
2. Sampling was performed by standard methods (stone-, core- and kick-sampling). The faunal communities were compared by Bray-Curtis similarity, diversity (H), saprobic index (SI) and Danish fauna index (DFI) methods.
3. Restoration with stream concentrators resulted in a deeper and narrower stream with a higher flow velocity near the bottom and a coarser substrate compared with the reference section. The fauna showed higher similarity to the fauna found on the stony bottom sections due to immigration of taxa preferring stony substrate (e.g.*Lepidostoma hirtum, Theodoxus fluviatilis*) and SI and DFI generally improved from II to/towards I-II. Clean-water species such as *Agapetus ochripes* and *Limnius volckmari*, were found in significantly higher numbers in the restored sections compared with the reference section.
4. Five times as many trout spawning redds occurred in the restored sections than in the non-restored. However, electro-fishing revealed few young-of-the-year trout and did not reflect spawning success
5. It was concluded that attempts to improve the physical structure and spawning environment altered invertebrate composition, but did not enhance trout production.

- 63 - Gowan C. & Faush K.D., 1996. Long-Term Demographic Responses of Trout Populations to Habitat Manipulation in Six Colorado Streams. Ecological Applications, 6(3) : 931-946.

Abstract : Fish communities in high-elevation, Rocky Mountain streams consist of only one or a few trout species, so these streams are ideal for quantifying how physical habitat manipulation influences population biology. Managers often alter habitat structure in hopes of increasing the number of size of fish in a population, but this practice has not been rigorously evaluated, and the mechanisms involved are not well understood. We measured fish abundance and habitat conditions in each half of 500-m study reaches in six streams for 2 yr before and 6 yr after installing 10 low log weirs in a randomly

designated half (treatment section). Mean depth, pool volume, total cover, and the proportion of fine substrate particles in the stream bed increased in treatment sections within 1 to 2 years, whereas habitat in adjacent controls remained unchanged. Abundance and biomass of adult fish, but not juveniles, increased in treatments relative to controls in all streams. Recaptures of trout that were individually tagged and others that were batch marked revealed that immigration was primarily responsible for increased adult abundance and biomass, whereas no biologically significant differences occurred for recruitment, survival, or growth. Few (<5%) immigrants to treatment sections came from adjacent controls, indicating that the increased adult abundance did not result simply from fish redistributing within the study reach, but was caused instead by immigration from beyond the reach boundaries. Immigration to control sections was frequent as well, leading us to conclude that fish movement was common, contrary to most literature on stream trout. We also detected a high degree of concordance in fish abundance fluctuations within and among streams, suggesting that regional factors influenced fish populations over large spatial scales. Our research shows that log weirs increase trout abundance, but only if other management activities assure that fish dispersal remains unimpeded within the drainage.

- 64 - Gowan C., Young M.K., Fausch K.D. & Riley S.C., 1994. Restricted movement in resident stream salmonids : a paradigm lost ? Canadian journal of fisheries and aquatic sciences, 51(11) : 2626-2637.

Keywords : aire déplacement • déplacement actif animal • limitation • sédentaire • résident • cours eau • théorie • Colorado • Wyoming • Salmonidae • Etats Unis • Amérique du Nord • Amérique • milieu eau douce • Pisces • Vertebrata.

Abstract : Gerking (1959. Biol. Rev. 34 : 221-242) a proposé une théorie sur la limitation du déplacement des poissons dans les cours d'eau que nous croyons être un paradigme en biologie des salmonidés. Selon cette théorie, nommée par nous paradigme de la limitation du déplacement, les salmonidés résidents des cours d'eau seraient sédentaires. De nombreuses études ont appuyé ce paradigme, mais presque toutes étaient fondées sur la recapture de poissons marqués dans les zones mêmes où ils avaient été libérés, une approche que nous croyons biaisée en ce qui concerne la détection du déplacement. Nous avons constaté un déplacement substantiel de truites dans des cours d'eau du Colorado et du Wyoming à l'aide de bordiques à deux voies et de la radiotélémesure. Une revue de la recherche effectuée dans le Lawrence Creek au Wisconsin a également montré que le déplacement était important dans la réponse de la population de truites à l'enrichissement de l'habitat. Le déplacement des poissons résidents des cours d'eau comporte d'importantes implications en recherche (p. ex., mesure de la production et modèles d'habitats) et en gestion (p. ex., enrichissement de l'habitat, réglementation particulière et stockage des écloseries). Des méthodes permettant de déceler le déplacement du poisson pourraient être intégrées à de nombreuses études afin d'évaluer son importance dans les systèmes en cause. De nouvelles théories et de nouvelles expériences sont nécessaires à la compréhension des mécanismes à l'origine du déplacement des salmonidés dans les cours d'eau.

- 65 - Grift R.E., Buijse A.D., Van Densen L.T. & Klein Breteler J.G.P., 2001. Restoration of the river-floodplain interaction: benefits for the fish community in the River Rhine. Archiv für Hydrobiologie, 12(2-4) : 173-185.

Abstract : In the lower River Rhine, canalization of the river and disconnection of floodplains from the river bed lead to the present low diversity of habitats. Spawning conditions for especially rheophilic cyprinids have declined dramatically. Nowadays, eurytopic species dominate the riverine fish community. In 1989, river restoration started by connecting water bodies in the floodplains to the main channel permanently. To evaluate the effect of these restorations on the fish community, four water bodies, which differ in connectivity with the main channel, flow velocity and presence of aquatic vegetation, were sampled to investigate their functions as spawning and nursery areas for riverine fishes. The hypothesis that density of rheophilic cyprinids is in accordance with flow and connectivity was tested by analysis of presence-absence data, using a logistic model and by analysis of variance for abundance data using a generalized linear model. Presence and abundance of rheophilic cyprinids increased from the isolated oxbow lake (not connected, no flowing water present) to connected oxbow lake (permanently connected with the main channel, no flowing water present) and to both secondary

channels (permanently connected with the main channel, flowing water present permanently). Connectivity of a water body with the main channel and the presence of flowing water are important factors driving the structure of the YOY fish community in floodplain water bodies. Only a few years after their creation, secondary channels provide a suitable habitat as nursery areas for rheophilic cyprinids.

- 66 - Habersack H. & Nachtnebel H.P., 2006. Short-term effects of local river restoration on morphology, flow field, substrate and biota. Regulated Rivers: Research & Management, 10(2-4) : 291-301.

Keywords : river restoration • morphology • substrates • flow fields.

Abstract : The objective of this paper is to analyse the short-term effects of restoration on river morphology, flow field, substrate and biota. One of the aims of the restoration measures is to arrest the degradation of the river Drau, which has caused technical (instability of bank protection measures) and ecological (loss of dynamic river reaches with alternate bars) problems. The restoration programme consists of several measures such as digging a new side channel on the right side, leaving an island and erection of groins on the left side of the main channel. These were made to keep the entrance open. After a two year monitoring programme the results of the analysis show that with respect to the river morphology, flow field and substrate, positive and negative effects were recorded, whereas for the ecology, positive effects were in general documented. Repeated morphological surveys using an echosounder showed that within a year without major flood events the main channel aggraded on average about 16 cm and the upper parts of the island degraded by up to 1 m. The groin pools became partially filled due to their function as sediment traps for finer material during low flows. Subsequent, measurements performed after several floods showed that degradation reduced the amount of aggradation by 50%. Flow velocity measurements demonstrated the effects of groins and their inability to force the main flow path to the side channel. In contrast with the main channel, the side channel was characterized by highly variable sediment grain sizes and dynamic morphological changes. The lower shear stresses and higher growth of algae in the side channel were associated with higher numbers of species of macroinvertebrates. Population studies showed significantly higher densities of fish species in this reach with a side channel than in any other river reach. Forty species of birds were observed, seven of which were typical water-related species, and the number of plant species increased from 48 to 118.

- 67 - Habersack H. & Piégay H., 2007. 27 River restoration in the Alps and their surroundings: past experience and future challenges. Developments in Earth Surface Processes 11 : 703-735.

Abstract : Alpine rivers have undergone significant changes over the two last centuries. Human activities have modified their geometry through engineering measures to gain land for agricultural purposes and settlements, as well as through active mining to exploit gravel resources. Their sediment and water transfers have also been altered by hydropower-plant construction, control works on high-gradient streams, and catchment land-use changes. The resulting river morphological changes have led to abiotic (e.g., river-bed degradation and narrowing) and biotic (e.g., longitudinal and lateral disconnection) disruption. The current critical management situation (channel instability problems, flood effects, biodiversity decrease) has made river restoration a major issue in the Alps and their surroundings. Such an approach is reinforced by the European Water Framework Directive, which aims to ensure that rivers attain a good ecological status by 2015.
In the Alps, space is not always easily available and boundary conditions have changed over the long term. A major challenge in river restoration in the Alpine environment is therefore to identify the processes and key parameters for improving both geomorphological and ecological conditions under often-restricted boundary conditions. Early attempts at river restoration mainly focused on small-scale measures. Today, successful restoration projects in high-energy and bedload-transport-dominated conditions must include the full spectrum of scales, striving to initiate self-forming morphodynamics.
In this context, we appraise restoration experiences from the Alps, focusing on channel widening and dike enlargement, former channel reconstruction and reconnection, promotion of bedload supply input from floodplains, tributaries, and hillslopes, as well as on bank erosion measures and restoration

activities. We discuss the basic arguments behind such actions, their limitations, and research challenges.

- 68 - Hamilton J.B., 1989. Response of juvenile steelhead to instream deflectors in a high gradient stream. Practical Approaches to Riparian Resource Management: An Educational Workshop. American Fisheries Society, Bethesda MD. p 149-158. 2 fig, 7 tab, 56 ref.

Abstract : Stream channel characteristics and juvenile steelhead Oncorhynchus mykiss populations were estimated before and after placement of boulder/rock triangular wing deflectors in 10 sections of a northern California stream in an effort to improve rearing habitat. An equal number of control sections were monitored. Following winter flows in 1981-1982, 14% of the structures were functionally intact. Changes in fry and parr numbers, densities, biomass, and standing crops in treated sections were not significantly different from changes in control sections. Condition factor of parr in 1982 was significantly reduced in treated sections following winter flows. A significantly lower percentage of marked parr remained in treatment sections following alteration. A review of similar habitat improvement evaluations indicated projects that increase populations have usually been sited on lower gradient (mean of 1.0%) stream reaches. Projects that did not demonstrate population increases were generally on higher gradient (mean of 1.8%) stream reaches, and results, although valuable, are less frequently published.

- 69 - Harper, D; Ebrahimnezhad, M; Cot, FCI, 1998. Artificial riffles in river rehabilitation: Setting the goals and measuring the successes. Aquatic Conservation: Marine and Freshwater Ecosystems, 8(1) : 5-16.

Abstract : Replacement of artificial riffles in canalized rivers is a widely-used tool in river rehabilitation but its effectiveness is only infrequently evaluated. In this paper artificial riffles, placed in a 2-km length of lowland stream in eastern England, were evaluated using geomorphological, functional habitat, and ecological techniques 3 years after installation. Mean riffle spacing was approximately double that predicted from first principles, due to several large 'gaps' in the 2-km length where riffles had not been originally reconstructed. Two sequences, of 14 riffles, did approximate to the spacing predicted for natural riffles based upon the relationship with mean annual discharge and with bankfull width. Twenty out of 26 riffles retained their original physical character whilst six were deep, slow flowing and covered with sand or silt. Shallow riffles in an approximately correct spacing retained their coarse particle dominance and caused the scouring between themselves of deeper pools than were found elsewhere in the stretch. Shallow riffles had high flow velocities which resulted in richness of functional habitats not found elsewhere in the stretch. Invertebrate colonization showed a clear distinction between communities of shallow, fast-flowing riffles and deeper slow-flowing runs and silted riffles. Indicator taxa of riffles were the genera *Baetis*, *Simulium*, *Hydropsyche*, *Eukieferiella*, and *Rheotanytarsus*. Indicator genera of silted riffles and runs were *Caenis*, *Planorbis*, *Sphaerium*, *Microtendipes*, and *Stichtochironomus*. Riffle reinstatement in lowland rivers of low energy will produce desirable geomorphological and ecological changes if the riffles are spaced according to geomorphological 'first principles', and are shallow (< 30 cm depth) under low-flow conditions: thus, simple science can set adequate goals at the design stage. Appraisal using the development of functional habitats at riffle sites provides a rapid technique for post-project appraisal, thus evaluating by ecological success the original hydrological goals.

- 70 - Harper D.M., Ebrahimnezhad M., Taylor E., Dickinson S., Decamp O., Verniers G. & Balbi T., 1999. A catchment-scale approach to the physical restoration of lowland UK rivers. Aquatic Conservation: Marine and Freshwater Ecosystems, 9(1) : 141-157.

Abstract :

1. This paper advocates a catchment-scale perspective for river restoration and for individual rehabilitation works even though, at present, such works are often small-scale and ad hoc in nature. The catchment-scale approach is the logical consequence of the application of fundamental principles of river science to the philosophy of river restoration.

2. The five principles that river restoration should incorporate are: i) the hierarchy of river systems; ii) the proportional relationships between discharge and channel dimensions; iii) the importance of the

physical and biological continua of natural rivers; iv) the four-dimensional nature of river systems; and v) the role of heterogeneity in maintaining biodiversity and that of disturbance in maintaining heterogeneity.

3. Two sets of examples are given to illustrate the need for these five principles. One set relates to the role of trees in river processes (and in river restoration), while the other relates to the rehabilitation of physical structures in rivers at a different scale.

4. The value of trees both for the maintenance of water quality and for their conservation value in upper-order rivers is demonstrated. This, combined with evidence elsewhere for trees as an integral part of the river-riparian ecotone, suggests the restoration of lowland headwater streams as being totally tree-influenced. In middle and lower reaches of rivers, it is important to restore the river-floodplain interactions. Continuity with groundwater through the hyporheos as a result of riffle-pool rehabilitation and flood-regeneration of meadows and alluvial forests should be the long-term vision for lower-reach restoration.

5. In the interim, piecemeal rehabilitation of the physical heterogeneity of the bed and banks in large rivers can be locally successful provided that it restores coarse particles and interstices where they are absent through artificial material and/or siltation, but not if it fails to recognize fully the importance of replacing lost heterogeneity.

- 71 - Harrison S.S.C., Pretty J.L., Shepherd D., Hildrew A.G., Smith C. & Hey R.D., 2004. The effect of instream rehabilitation structures on macroinvertebrates in lowland rivers. Journal of Applied Ecology, 41 : 1140–1154.

Key-words : artificial riffles • flow deflectors • river restoration • macrophytes • benthos • restoration.

Summary

1. Many lowland rivers in Western Europe have been substantially modified to aid land drainage and support the intensification of agriculture. Although there have been many attempts at rehabilitation, few have been systematically evaluated on ecological criteria.

2. Macroinvertebrates were assessed in 13 UK lowland rivers containing instream rehabilitation structures, seven with artificial riffles (intended to mimic natural gravel riffles) and six with flow deflectors (intended to increase flow, depth and substrate heterogeneity within the channel). In each river, invertebrates were compared between stretches of river with and without rehabilitation structures.

3. Rehabilitated and reference stretches were subdivided into different benthic and macrophyte habitats. Three macroinvertebrate samples were taken once in July/August 1999 from each habitat across all schemes and rivers. Current velocity, depth and substratum particle size were recorded at the same time from each habitat.

4. Artificial riffle benthos had faster current, a coarser substratum and was shallower than reference benthos. Depth and substratum particle size differed little between flow deflector and reference benthos, although velocity downstream of the deflector tip was greater, and velocity in the lee of the deflector lower, than reference benthos. At a habitat scale, the benthos of artificial riffles, but not flow deflectors, had higher abundance, taxon richness and diversity than reference benthos. The impact of artificial riffles was most marked for benthic rheophilic taxa.

5. In all rivers, macroinvertebrate diversity was highest in marginal macrophytes and abundance highest in instream macrophytes. Although invertebrate communities were distinct between artificial riffle (but not flow deflector) and reference benthos, these differences were negligible in comparison to those between benthic and macrophyte habitats.

6. Neither artificial riffles nor flow deflectors had any significant impact on the taxon richness of the benthos or of the rehabilitated stretch of the river as a whole. Invertebrate diversity of rehabilitated stretches related closely to that of reference stretches, indicating that larger scale factors constrained any impact of rehabilitation.

7. *Synthesis and applications* **:** Local rehabilitation structures appeared to have minor biological effects in lowland rivers. We suggest that post-project appraisal should be more rigorously applied to rehabilitation schemes, measuring success against more clearly defined goals. We also advocate a greater emphasis on large-scale riparian, floodplain and catchment rehabilitation, rather than small-scale channel rehabilitation. Such a change in approach needs more effective cooperation and collaboration between all catchment users.

- 72 - Hassett B.A., Palmer M.A. & Bernhardt E.S., 2007. Evaluating Stream Restoration in the Chesapeake Bay Watershed through Practitioner Interviews. Restoration Ecology, 15(3) : 563–572.

Abstract : River restoration is an integral part of restoring the Chesapeake Bay. As part of the National River Restoration Science Synthesis (NRRSS), we conducted 47 independent interviews with stream restoration project managers randomly selected from a database of 4,700 projects in the Chesapeake Bay watershed. Here we present results from those interviews and characterize patterns in project goals, design, and expenditures, trends in project evaluation, and characterize project success as reported by interviewees. Interviewed practitioners reported that the majority of their projects were designed by private consultants. One-third of projects were part of a watershed management plan and 70% were linked to other projects within the same watershed. Most interviewees considered their projects to be successful, and 76% of projects had conducted some form of project-associated monitoring. Although most interviewees based their evaluation of success on observations or monitoring data, respondents indicated that very few projects had explicitly stated quantifiable project objectives within their design plans. Many interviewed practitioners specifically commented at the end of the surveys on the important role of stakeholder involvement and the need for initiatives to fund project monitoring.

- 73 - Helfield J.M., Capon S.J., Nilsson C., Jansson R. & Palm D., 2007. Restoration of rivers used for timber floating effects on riparian plant diversity. Ecological Applications, 17(3) : 840–851.

Key words: biodiversity • boreal • flooding • fluvial disturbance • forest • restoration • riparian • river • Sweden • timber floating • vegetation.

Abstract : Fluvial processes such as flooding and sediment deposition play a crucial role in structuring riparian plant communities. In rivers throughout the world, these processes have been altered by channelization and other anthropogenic stresses. Yet despite increasing awareness of the need to restore natural flow regimes for the preservation of riparian biodiversity, few studies have examined the effects of river restoration on riparian ecosystems. In this study, we examined the effects of restoration in the Ume River system, northern Sweden, where tributaries were channelized to facilitate timber floating in the 19th and early 20th centuries. Restoration at these sites involved the use of heavy machinery to replace instream boulders and remove floatway structures that had previously lined stream banks and cut off secondary channels. We compared riparian plant communities along channelized stream reaches with those along reaches that had been restored 3–10 years prior to observation. Species richness and evenness were significantly increased at restored sites, as were floodplain inundation frequencies. These findings demonstrate how river restoration and associated changes in fluvial disturbance regimes can enhance riparian biodiversity. Given that riparian ecosystems tend to support a disproportionate share of regional species pools, these findings have potentially broad implications for biodiversity conservation at regional or landscape scales.

- 74 - Hendry K., Gragg-Hine D., O'Grady M., Sambrook H. & Stephen A., 2003. Management of habitat for rehabilitation and enhancement of salmonid stocks. Fisheries Research, 62(2) : 171-192.

Keywords : Salmon • Trout • habitat • water quality • water quantity • flow • physical structure • management • restoration.

Abstract : Most of the river systems in the British Isles have been subjected to anthropogenic influence to varying degrees over recent times, in many instances leading to deleterious impacts on salmonid habitat to the detriment of populations. This paper considers the range of management options that can be utilised to overcome habitat degradation. When examining salmonid habitat management three areas need to be taken into account: water quality, water quantity and the physical structure of the riverine environment. Although discussed separately, it should be remembered that these components of habitat are inter-related, and should be viewed as a continuum. Water quality problems include pollution from point and non-point source pollutants, although major improvements in

the former have been achieved in recent years via the legislative framework and further benefits may be anticipated from the introduction of the Water Framework Directive. However, diffuse forms of pollutant, notably silt, still remain a significant threat to salmonid habitat and are yet to be tackled in any meaningful way. Changes to modern agricultural and land management practices are urgently required. Water quantity is impacted upon in a number of ways ranging from abstraction, which may reduce flows, through to land-use and flood defence that may alter the shape of the hydrograph changing velocities and influencing stream power. Society's conflicting demands are bound to increase these pressures, although imaginative and integrated planning of schemes can avoid many deleterious impacts and actually provide benefits to salmonid populations, provided the ecological requirements of the species are taken into account. Arguably a more flexible and targeted approach to river regulation and abstraction would be beneficial to salmonid populations. Degradation of physical stream habitat has been widespread caused primarily by insensitive land-use practices, agriculture and flood defence. A significant commitment to consider long-term investment of resources will be required to negate the widespread deterioration in habitat caused by such damaging management techniques. Although a wide range of physical habitat restoration techniques have been demonstrated both in-stream and within the riparian zone with significant success, it is suggested that some form of land-use regulation is required to prevent further damage. Treating the root cause of the problems of deterioration with respect to water quality, quantity and physical habitat, and not just the symptoms, should be a fundamental priority for salmonid management in the 21st century.

- 75 - Henry C.P. and Amoros C., 1996. Restoration ecology of riverine wetlands. III. Vegetation survey and monitoring optimization. Ecological Engineering 7(1) : 35-58.

Keywords: biodiversity • former river channel • macrophyte • multivariate data analysis • reduction of monitoring effort • restoration impacts and success assessment • Rhône River.

Abstract : A restoration experiment was carried out in a former channel of the Rhône River, France. To evaluate restoration success or failure, aquatic vegetation was surveyed monthly from March to October, one year prior to and 2 years following restoration. This was done in both the channel restored by the dredging of fine organic nutrient-rich sediments and in a similar reference channel. Whereas both species richness and total vegetational cover per transect of aquatic vegetation showed the same temporal pattern each year in each zone, these two variables exhibited a different pattern in the restored channel after restoration. Species richness generally increased continuously during the first year following restoration, then followed a seasonal pattern during the second year. Total vegetational cover was very low the first year following restoration and remained low afterwards, except in the upstream zone of the restored channel, which was fully colonized by aquatic vegetation the second year. Post-restoration changes were thus very clear in the upstream zone of the restored channel. A multivariate analysis depicted changes in the floristic composition: whereas vegetation composition was quite stable in the reference channel, eutrophic species were replaced by mesotrophic species in the restored channel

- 76 - Henry C.P., Amoros C. & Roset N., 2002. Restoration ecology of riverine wetlands: A 5-year post-operation survey on the Rhône River, France. Ecological Engineering, 18(5) : 543-554.

Keywords: aquatic vegetation • former river channels • hydroelectric scheme impact • long-term study • multivariate data analysis • restoration assessment • Rhône River • succession.

Abstract : Bibliographical study of articles published in scientific journals over the last 10 years, and of books published over the last 20 years, reveals a clear increase in the number of publications dealing with ecological engineering, particularly on aquatic ecosystems, which today are becoming a major topic. The concept of ecological restoration must be clearly defined scientifically and include adequate pre- and post-restoration monitoring of various performance indicators, to allow for restoration, evaluation and increase its success. A restoration experiment was carried out in a former channel of the Rhône River according to a scientifically based decision framework. Long-term monitoring of aquatic vegetation (17 years of data) on two former channels (reference and restored ecosystem) clearly demonstrated human impacts on aquatic ecosystems. A channel exhibiting rapid terrestrialization and eutrophication processes after completion of a hydroelectric scheme construction was restored. In keeping with the hypothesis, the increase in groundwater supply led the restored

ecosystem to return to a less advanced and self-sustainable successional stage, whereas vegetation monitoring in the reference channel did not show significant changes over this 17-year of period, supporting long-term studies to determine the effects of restoration on the biota.

- 77 - Hilderbrand R.H., Lemly A.D., Dolloff C.A. & Harpster K.L., 1997. Effects of large woody debris placement on stream channels and benthic macroinvertebrates. Canadian Journal of Fisheries and Aquatic Sciences, 54(4): 931–939.

Abstract: Large woody debris (LWD) was added as an experimental stream restoration technique in two streams in southwest Virginia. Additions were designed to compare human judgement in log placements against a randomized design and an unmanipulated reach, and also to compare effectiveness in a low- and a high-gradient stream. Pool area increased 146% in the systematic placement and 32% in the random placement sections of the low-gradient stream, lending support to the notion that human judgement can be more effective than placing logs at random in low-gradient streams. Conversely, the high-gradient stream changed very little after LWD additions, suggesting that other hydraulic controls such as boulders and bedrock override LWD influences in high-gradient streams. Logs oriented as dams were responsible for all pools created by additions regardless of stream or method of placement. Multiple log combinations created only two pools, while the other seven pools were created by single LWD pieces. Total benthic macroinvertebrate abundance did not change as a result of LWD additions in either stream, but net abundances of Plecoptera, Coleoptera, Trichoptera, and Oligochaeta decreased, while Ephemeroptera increased significantly with the proportional increase in pool area in the low-gradient stream.

Résumé : De gros débris ligneux (GDL) ont été ajoutés dans deux cours d'eau dans le sud-ouest de la Virginie pour étudier une technique expérimentale de remise en état des cours d'eau. Ces débris ont été ajoutés pour comparer le jugement humain dans le placement des billes de bois par rapport à un placement aléatoire et à un tronçon non manipulé, et également pour comparer l'efficacité de ces méthodes dans un ruisseau à forte déclivité et dans un ruisseau à faible déclivité. La superficie de la nappe d'eau a augmenté de 146% dans le cas du placement systématique comparativement à 32% dans les tronçons à placement aléatoire du ruisseau à faible déclivité, ce qui sous-tend l'idée que le jugement humain peut être plus efficace que le hasard dans le placement des billes dans les ruisseaux à faible déclivité. Inversement, le ruisseau à forte déclivité a très peu changé après l'addition de GDL, ce qui donne à entendre que d'autres facteurs hydrauliques tels les rochers et le substratum rocheux, l'emportent sur les effets des GDL dans les ruisseaux à forte déclivité. Les billes orientées de manière à former des barrages ont été à l'origine de tous les bassins créés par addition quel que soit le ruisseau ou la méthode de placement. Les combinaisons de plusieurs billes n'ont créé que deux bassins, tandis que les sept autres bassins ont été le fait de GDL uniques. L'abondance totale des macroinvertébrés benthiques n'a pas changé par suite de l'addition de GDL dans l'un ou l'autre type de ruisseau, mais l'abondance nette de plécoptères, de coléoptères, de trichoptères et d'oligochètes a diminué alors que celle des éphéméroptères a augmenté de manière statistiquement significative en fonction de l'augmentation de la superficie de bassins dans le ruisseau à faible déclivité.

- 78 - Hilderbrand R.H., Lemly A.D., Dolloff C.A. & Harpster K.L., 1998. Design Considerations for Large Woody Debris Placement in Stream Enhancement Projects. North American Journal of Fisheries Management, 18(1) : 161-167.

Abstract : Log length exerted a critical influence in stabilizing large woody debris (LWD) pieces added as an experimental stream restoration technique. Logs longer than the average bank-full channel width (5.5 m) were significantly less likely to be displaced than logs shorter than this width. The longest log in stable log groups was significantly longer than the longest log in unstable groups. The distances moved by displaced logs demonstrated a quadratic relationship associated with log length; longer logs moved less often, but they moved farther when entrained in the current than the majority of mobile smaller logs. Log stability did not differ between a treatment section with randomized placement of LWD and a section in which LWD was placed systematically to best modify channel habitats. Channel scouring typically occurred around LWD oriented as ramps and as dams perpendicular to stream flow; aggradation occurred above and below pieces oriented as dams angled to the current. Microscale channel responses to LWD additions varied.

- 79 - Hill M.T. & Platts W.S., 1998. Ecosystem Restoration: A Case Study in the Owens River Gorge, California. Fisheries, 23(11) : 18-27.

Abstract : In 1991 the Los Angeles Department of Water and Power, in cooperation with Mono County, California, initiated a multiyear effort to restore the Owens River Gorge. The project aims to return the river channel, dewatered for more than 50 years, to a functional riverine-riparian ecosystem capable of supporting healthy brown trout and wildlife populations. The passive, or *natural*, restoration approach focused on the development of riparian habitat and channel complexity using incremental increases in pulse (freshet) and base flows. Increasing pulse and base flows resulted in establishment and rapid growth of riparian vegetation on all landforms, and the formation of good-quality micro-habitat features (pools, runs, depth, and wetted width). An extremely complex, productive habitat now occupies the bottom lands of the Owens River Gorge. A healthy fishery in good condition has quickly developed in response to habitat improvement. Brown trout numbers have increased each year since initial stocking, 40% between 1996 and 1997. Catch rates increased from 0 fish/hr in 1991 to 5.8–7.1 fish/hr (with a maximum catch rate of 15.7 fish/hr) in 1996. Restoring the Owens River Gorge bridges the theoretical concepts developed by Kauffman et al. (1997) and the practical application of those concepts in a real-time restoration project.

- 80 - Hoffmann C.C., Pedersen M.L. , Kronvang B. & Øvig L., 1998. Restoration of the Rivers Brede, Cole and Skerne: a joint Danish and British EU-LIFE demonstration project, IV - implications for nitrate and iron transformation. Aquatic Conservation: Marine and Freshwater Ecosystems, 8(1) : 223-240.

Key-words : denitrification • floodplain • pyrite oxidation • restoration.

Abstract :

1. The possible effects on the hydrological and biogeochemical processes in the River Brede valley were studied from August 1994 to August 1996 based on measurements in piezometers installed along four transects across the river valley and two river monitoring stations located immediately upstream and downstream of the restored reach.
2. Groundwater discharge to the river varied considerably both along the restored river reach and from bankside to bankside. Comparison of the water balance derived from two river monitoring stations and the groundwater balance for the restored part of the river valley, based on Darcy's equation, indicated that a deep-lying regional aquifer probably discharges to the river in the restored area.
3. The nitrate balance for the floodplain revealed that 92 kg NO_3-N ha^{-1} $year^{-1}$ was removed during passage through the river valley, probably as a result of pyrite oxidation. In contrast, iron leaked from the floodplain to the river at the rate of 400 kg Fe ha^{-1} $year^{-1}$.
4. A prolonged dry period, starting four months after completion of the restoration work and lasting for the remainder of the study period, makes it difficult to conclude whether the results obtained are reflective of river and floodplain restoration. Nitrate concentration measurements at the two river monitoring stations revealed no overall significant changes when comparing a pre-restoration period with two similar post-restoration periods. However, comparison of nitrate losses from an upstream control catchment and the restored reach catchment indicated enhanced removal of nitrate along the restored river reach during a three month period of flooding immediately following completion of restoration work (January to March 1995).

- 81 - Hohausova E. & Jurajda P. 2005. Restoration of a river backwater and its influence on fish assemblage. Czech Journal of Animal Science, 50 (10): 473-482.

Keywords : rehabilitation • monitoring • colonisation • floodplain • Morava River • assemblage development • adult fish • 0+ fish • freshwater.

Abstract : The development of fish assemblage in a restored river backwater (Kurfürst backwater, Morava River, Czech Republic) was monitored over a six-year period from its restoration. The structure of fish assemblage remained similar throughout the years. Species richness of adult fish increased from twelve species during the restoration to 20 after it. Initially steady fish abundance (mean 52.3–98.1 inds/ha) and biomass (mean 5.8–7.6 kg/ha) increased significantly in 1999 five years

after restoration (576.9 inds/ha and 23.3 kg/ha, respectively). The main resident species were pike *Esox lucius*, roach *Rutilus rutilus*, rudd *Scardinius erythrophthalmus* and perch *Perca fluviatilis*. High abundance of bleak *Alburnus alburnus* and chub *Leuciscus cephalus* was related to their spring spawning period. The structure of the 0+ fish assemblage was similar throughout the years, with chub and bleak prevailing during the restoration, and roach, chub and rudd after it. The number of 0+ species increased from seven to 17. The monitoring documented that the restoration could be considered as beneficial for the fish assemblage. Habitat development of the backwater is likely to influence its current value as a refuge, spawning site and nursery for local fish populations.

- 82 - House R. & Boehne P.L., 1985. Evaluation of Instream Enhancement Structures for Salmonid Spawning and Rearing in a Coastal Oregon Stream. North American Journal of Fisheries Management, 5(2b) : 283-295.

Abstract : East Fork Lobster Creek, Oregon is an example of a stream that lost much of its productivity as an anadromous salmonid stream following logging activities, intensive stream cleaning, and flooding. The stream in the study area was almost devoid of instream structures, resulting in a nearly total lack of spawning gravel and rearing habitat. Stream enhancement structures installed in East Fork Lobster Creek were successful and functional after two winters with usual freshets. The structures dramatically increased the diversity of the stream bed, trapped gravel, and created shallow gravel bars and deep, covered pools. Also, the number, size, and quality of the pools increased in areas with structures. Coho salmon (*Oncorhynchus kisutch*) and steelhead (*Salmo gairdneri*) spawning increased substantially, as well as the numbers of rearing coho, steelhead fry, and steelhead and cutthroat trout (*Salmo clarki*) parr. This study shows that similar degraded streams can be rehabilitated by properly designed enhancement programs. Such programs are effective and are needed to help ensure the protection of naturally spawning and rearing wild salmonid stocks and the survival of their young.

- 83 - House R. & Boehne P.L., 1986. Effects of Instream Structures on Salmonid Habitat and Populations in Tobe Creek, Oregon. North American Journal of Fisheries Management, 6(1) : 38-46.

Abstract : Tobe Creek, Oregon, was studied in 1982 and 1983 to compare physical and biological differences between a young-alder stream section logged and cleaned of large debris 20 years ago and a mature mixed-conifer section unlogged and containing large amounts of large woody debris. Stream enhancement techniques were used in 1982 to simulate large woody debris in the logged alder section to try to increase salmonid use. Large woody debris in the channel caused the development of secondary channels, meanders, pools, and undercut banks in the unlogged, mature-conifers, stream section. These elements were noticeably missing in the young-alder section. The mature-conifer section had more than twice as many pools and 10 times the amount of spawning gravel compared to the young-alder section. Salmonid biomass was significantly greater in the mature-conifer than the young-alder section prior to stream enhancement; after enhancement, no significant difference was found. Prior to enhancement, three times as many coho salmon (*Oncorhynchus kisutch*) and trout fry (cutthroat trout and steelhead) were living in the mature-conifer stream section. There was a positive correlation between coho salmon numbers and the presence of large woody debris. The study revealed that structure is most likely a more important factor than shade in governing a stream's capacity for producing salmonids.

- 84 - House R., 1996. An Evaluation of Stream Restoration Structures in a Coastal Oregon Stream, 1981–1993. North American Journal of Fisheries Management, 16(1) : 272-281.

Abstract : A 1.7-km reach of East Fork Lobster Creek, an Oregon coastal tributary of the Alsea River, was treated with mostly full-spanning, rock-filled gabions in 1981 and boulder structures in 1987. East Fork Lobster Creek (EFLC) supports runs of coho salmon *Oncorhynchus kisutch* and fall chinook salmon *O. tshawytscha*, winter steelhead *O. mykiss*, and sea-run and resident cutthroat trout *O. clarki*. The main objective of treatment was to improve spawning and summer rearing habitat for coho salmon, habitat determined to be lacking during 1980 surveys. Freshets in the winter of 1981–1982 filled all gabion structures with large gravel; the surface area of pool and low-gradient riffle habitats

increased but area of high-gradient riffle habitat decreased. From 1985 through 1993, the average number of coho salmon spawners in EFLC increased 2.5 times compared with returns during 1981–1984. In EFLC, treated areas supported significantly more juvenile coho salmon and cutthroat trout and had higher overall salmonid biomass than control areas, whereas age-0 trout (cutthroat trout plus steelhead) and juvenile steelhead showed no increases. For the entire 1.7-km reach receiving treatment, the number of coho salmon juveniles was higher after than before treatment, whereas numbers of steelhead and cutthroat trout fry and juveniles remained constant. Between 1981 and 1992, over 50% of the coho salmon and steelhead spawned on newly deposited, higher-quality gravels associated with 15 gabion structures that fully spanned the bank-full channel width. Quality of gravels impounded by gabions equaled or exceeded the quality of gravels in unmodified areas of the creek. Habitats, primarily pools, created by gabion structures lasted 10 years; however, disintegration of wire mesh tops starting in 1989 caused a slow reduction in pool habitat and gravel riffles at treated sites. All boulder structures remained functional in 1992. Results of this study provide some evidence that interim instream restoration to improve degraded streams and increase salmonid stocks at risk of extinction can be used until long-term watershed restoration strategies have been implemented.

- 85 - Hunt R.L., 1976. A Long-Term Evaluation of Trout Habitat Development and Its Relation to Improving Management-Related Research. Transactions of the American Fisheries Society, 105(3) : 361-364.

Abstract : Responses of a wild brook trout (*Salvelinus fontinalis*) population to instream habitat development in a 0.7 km reach of Lawrence Creek were monitored for 7 years and compared to population data for the 3-year period prior to development. Mean annual biomass of trout, mean annual number of trout over 15 cm (legal size), and annual production increased significantly during the 3 years following development, but more impressive responses were observed during the second 3 years. Maximum number and biomass and number of legal trout did not occur until 5 years after completion of development. The peak number of brook trout over 20 cm was reached the sixth year after development.
Where long-term studies of aquatic systems are needed to evaluate effects of environmental perturbations, it may be desirable to deliberately delay collection of posttreatment data. Such a start-pause-finish sequence of research would provide more valid and less costly evaluations and utilize the time of researchers more efficiently.

- 86 - Huuskö A. & Yrjäna T., 1995. Evaluating habitat restoration of rivers channelized for log transport : a case study of the River Kutinjoki, Northern Finland. Bulletin français de la pêche et de la pisciculture, 68 : 407-413.

Keywords : restauration milieu • aménagement hydraulique • choix habitat • vitesse écoulement ; • profondeur • substrat • cours eau • classe âge • Finlande • Salmo trutta • Salmonidae • Europe • milieu eau douce • gestion population • Pisces • Vertebrata.

Abstract : Au cours de la dernière décennie, plusieurs projets de restauration de rivières à grande échelle ont été initiés en Finlande, afin de réhabiliter la structure originale de l'habitat dans des rivières chenalisées pour le flottage du bois dans les années 1950-1960. L'objectif principal de la restauration est d'augmenter la diversité des berges et d'améliorer l'habitat des poissons en réarrangeant le substrat sur le fond de la rivière. Les digues de blocs utilisées sur la rivière Kutinjoki ont augmenté la diversité et la variabilité des profondeurs, des vitesses et des classes de substrats dominants disponibles, et ont augmenté la complexité spatiale des rapides. Sur les sites étudiés, les successions radiers-mouilles étaient clairement visibles après restauration et contrastaient avec les écoulements plus ou moins homogènes d'avant restauration. L'opération de restauration semble favoriser les truites de un an (1+) et plus. Si l'on souhaite planifier et évaluer ce type d'amélioration de l'habitat piscicole, il est fortement conseillé d'utiliser une modélisation des conditions physiques et hydrologiques à une échelle pertinente pour les poissons et d'y inclure une analyse des préférences d'habitat des poissons.

- 87 - Huuskö A. & Yrjäna T., 1997. Effects of instream enhancement structures on brown trout, *Salmo trutta* L., habitat availability in a channelized boreal river: a PHABSIM approach. Fisheries Management and Ecology, 4(6) : 453-466.

Abstract : Stream channel morphology and hydraulic conditions were measured before and after channel modification and boulder structure placements in a channelized boreal river to determine whether more favourable rearing habitat for brown trout, *Salmo trutta* L., was created. The assessment was performed using physical habitat simulation (PHABSIM) procedures based on summer and winter habitat preferences of brown trout for depth, velocity and substrate. The results showed that the availability of potential physical trout habitat can be increased in the study river at simulated low and moderate flow conditions by reconstruction of the river bed and placing instream boulder structures. The resulting diversity of depth and velocity conditions created a spatially more complex microhabitat structure. Improved habitat conditions were able to sustain a larger trout population. Hydraulic habitat models, like the PHABSIM framework, seem to be a suitable procedure to evaluate the benefits of physical habitat enhancement.

- 88 - Hvidsten N.A. & Johnsen B.O., 1992. River bed construction: Impact and habitat restoration for juvenile Atlantic salmon, Salmo salar L., and brown trout, Salmo trutta L. Aquaculture and Fisheries Management., 23(4) : 489-498.

Abstract : The River Soeya, Norway, was canalized for agricultural purposes. To compensate for damage to the Atlantic salmon, *Salmo salar* , and brown trout, *Salmo trutta* populations, different weirs were built. The aims of this study were to analyse the effects of weirs covering the river bank and entire river bottom with blasted stones and to analyse the effects of sediments transported by freshets on the downstream salmon and trout populations after canalization. Restoration of the river bottom with blasted stones provided salmon with more substrate space. Densities of trout increased after the river bank was covered with stones. Sediments transported downstream from the canalized river stretch decreased the densities of juvenile salmon and trout.

- 89 - Iversen T.M., Kronvang B., Madsen B.L., Markmann P. & Nielsen M.B., 2006. Re-establishment of Danish streams: Restoration and maintenance measures. Aquatic Conservation: Marine and Freshwater Ecosystems, 3(2) : 73-92.

Abstract :

1- Prior to 1983 the Danish legislation concerning streams gave priority to drainage of water. The revision of The Watercourse Act gave balanced priority to drainage of water and environmental quality, focusing on an ecologically more appropriate maintenance practice and giving special provisions for stream restoration activities.

2- Different measures of single structure restoration have been used, the most common being replacement of weirs, dams or other obstacles by rapids, establishment of salmonid spawning grounds, and installation of new or improved fish ladders.

3- The most common stream channel restoration method is integrated use of a number of single structure measures. Establishment of a two-stage channel and re-opening of small piped streams have also been used. Stream valley restoration includes restoration of old meanders or establishment of a new sinuous channel and involves the adjacent riparian areas.

4- The changed stream maintenance practice involves a new strategy for dredging and cutting of weeds and bank vegetation in order to minimize the ecological damage caused by keeping a reasonable discharge capacity. In 1990, environmentally acceptable weed-cutting was performed in 37% of all municipal streams and the bank vegetation was left uncut in a third of the streams. Similarly, more than half of the county streams were maintained using hand scythes and in 74% of the streams the bank vegetation was left uncut.

5- Quantitatively, stream restoration has contributed little to the general improvement of Danish streams compared with changed maintenance practice. Stream restoration projects create public interest in the environmental quality of streams, but major improvements in the physical properties of Danish streams depend on future maintenance practice.

6- Due to major changes predicted in Danish agriculture many riparian areas and wetlands will reappear and the natural or semi-natural physical properties of streams will be re-established by

natural processes or changed in maintenance practice. However, there will still be large areas with intensive agriculture, where environmental and agricultural interests must be balanced. The Danish experience has shown that this is possible.

- 90 - Jansson R., Nilsson C. & Malmqvist B., 2007. Restoring freshwater ecosystems in riverine landscapes: the roles of connectivity and recovery processes. Freshwater Biology, 52(4) : 589–596.

Abstract :

1- This paper introduces key messages from a number of papers emanating from the *Second International Symposium on Riverine Landscapes* held in August 2004 in Sweden, focusing on river restoration. Together these papers provide an overview of the science of river restoration, and point out future research needs.

2- Restoration tests the feasibility of recreating complex ecosystems from more simple and degraded states, thereby presenting a major challenge to ecological science. Therefore, close cooperation between practitioners and scientists would be beneficial, but most river restoration projects are currently performed with little or no scientific involvement.

3- Key messages emanating from this series of papers are: The scope, i.e. the maximum and minimum spatial extent and temporal duration of habitat use, of species targeted for restoration should be acknowledged, so that all relevant stages in their life cycles are considered. Species that have been lost from a stream cannot be assumed to recolonise spontaneously, calling for strategies to ensure the return of target species to be integrated into projects. Possible effects of invasive exotic species also need to be incorporated into project plans, either to minimise the impact of exotics, or to modify the expected outcome of restoration in cases where extirpation of exotics is impractical.

4- Restoration of important ecological processes often implies improving connectivity of the stream. For example, longitudinal and lateral connectivity can be enhanced by restoring fluvial dynamics on flood-suppressed rivers and by increasing water availability in rivers subject to water diversion or withdrawal, thereby increasing habitat and species diversity. Restoring links between surface and ground water flow enhances vertical connectivity and communities associated with the hyporheic zone.

5- Future restoration schemes should consider where in the catchment to locate projects to make restoration most effective, consider the cumulative effects of many small projects, and evaluate the potential to restore ecosystem processes under highly constrained conditions such as in urban areas. Moreover, restoration projects should be properly monitored to assess whether restoration has been successful, thus enabling adaptive management and learning for the future from both successful and unsuccessful restorations.

- 91 - Jenkinson R.G., Barnas K.A., Braatne J.H., Bernhardt E.S., Palmer M.A., Allan J.D. & The National River Restoration Science Synthesis, 2006. Stream Restoration Databases and Case Studies: A Guide to Information Resources and Their Utility in Advancing the Science and Practice of Restoration. Restoration Ecology, 14(2) : 177–186.

Abstract : The successful application of adaptive management to the science and practice of restoration ecology requires specific knowledge about the outcomes of past restoration efforts. Ideally, project results would be readily available to scientists or other project managers with similar goals or in analogous ecosystems. Recently, there has been a proliferation of Internet-accessible databases, lists, and case studies of stream and river restoration projects. These resources include a wide range of information that could be accessed to aid natural resource and conservation professionals in restoration. In the U.S. Pacific Northwest, the National Marine Fisheries Service's Northwest Fisheries Science Center and, on a national scale, the National River Restoration Science Synthesis are combining existing national and regional databases, along with the individual project descriptions, to create comprehensive, web-based databases of stream restoration projects. In this process, more data sources were discovered than fit the scope of either of these projects. Ten international, 19 U.S. national, and 42 U.S. regional web-accessible sources of restoration project databases and case studies are listed in this study. However, to easily use information that is currently scattered in multiple files and Web sites, databases would optimally use a common, standardized format. We provide a

recommended list of information to be included in restoration databases. These efforts may provide a blueprint for development of compatible international databases of stream restoration projects.

- 92 - Jones N.E., Tonn W.M., Scrimgeour G.J. & Katopodis C., 2003. Productive capacity of an artificial stream in the Canadian Arctic: assessing the effectiveness of fish habitat compensation. Canadian Journal of Fisheries and Aquatic Sciences, 60(7) : 849–863.

Abstract: Few fish habitat compensation projects are assessed with respect to the principle of "no net loss" of productive capacity. Using reference streams as standards against which gains and losses of functions (e.g., production of fish) could be quantified, we examined the effectiveness of a 3.4-km artificial stream in the Northwest Territories, Canada. The artificial stream restored watershed connectivity, allowing fish migration and provided spawning and nursery habitat, particularly for Arctic grayling (*Thymallus arcticus*). However, the average mass of young-of-the-year (YOY) grayling at the end of summer was lower (57%) in the artificial stream than in natural streams. This difference in growth, in concert with estimates of grayling density, meant that the standing crop produced in the artificial stream averaged 37% of that found in natural streams. A bioenergetics model indicated that cooler water temperatures in the artificial stream had limited influence on growth. Instead, low amounts of autochthonous and allochthonous organic matter and poor physical habitat in the artificial stream appeared to limit the productivity of benthic invertebrates and fish. Our explicit analysis of productive capacity will allow future compensation measures to focus on deficiencies in the artificial stream and on the improvement of its productive capacity as fish habitat.

Résumé : Peu de projets de compensation d'habitat de poissons sont évalués en tenant compte du principe qu'il doit n'y avoir « aucune perte nette » de capacité de production. En utilisant des cours d'eau témoins comme points de référence pour quantifier les gains et les pertes fonctionnelles (e.g., la production de poissons), nous avons évalué l'efficacité d'un cours d'eau artificiel de 3,4 km dans les Territoires du Nord-Ouest, Canada. Le cours d'eau artificiel a rétabli la connectivité du bassin hydrographique, permis la migration des poissons et fourni des habitats de fraye et de développement des alevins, en particulier pour l'ombre arctique (*Thymallus arcticus*). Cependant, la masse moyenne de petits ombres de l'année (YOY) à la fin de l'été est plus faible (57 %) dans le cours d'eau artificiel que dans les cours d'eau naturels. Ces différences de croissance, combinées aux estimations de densité, font que la biomasse produite dans le cours d'eau artificiel représente en moyenne 37 % de celle qui existe dans les cours d'eau naturels. Un modèle bioénergétique démontre que les eaux plus fraîches du cours d'eau artificiel n'ont qu'une influence mineure sur la croissance. En revanche, les faibles quantités de matière organique autochtone et allochtone et l'habitat physique inadéquat du cours d'eau artificiel semblent limiter la productivité des invertébrés benthiques et des poissons. Notre analyse explicite de la capacité de production fait en sorte que les mesures de compensation futures pourront cibler les déficiences du cours d'eau artificiel et chercher à améliorer sa capacité de production comme habitat pour le poisson.

- 93 - Jones N.E. & Tonn W.M., 2004. Enhancing Productive Capacity in the Canadian Arctic: Assessing the Effectiveness of Instream Habitat Structures in Habitat Compensation. Transactions of the American Fisheries Society, 133(6) : 1356-1365.

Abstract : We examined the effectiveness of physical habitat structures (ramps, V-weirs, vanes, and groins) at increasing the productive capacity of a newly created 3.4-km artificial stream in the Barrenlands region of the Northwest Territories, Canada. We quantified changes in fish density and growth in the immediate area of each structure and for the artificial stream as a whole using before–after–control–impact approaches. Emphasis was on young-of-the-year (hereafter, age-0) Arctic grayling *Thymallus arcticus*, the dominant fish in the artificial and nearby natural streams. Structures attracted significantly higher densities of fish than did nearby reference sections, yet the age-0 Arctic grayling at the structures did not experience any density-dependent reduction in growth, suggesting that structures provided energetically favorable microhabitats. Relative to reference streams and prestructure conditions, however, the addition of these physical structures did not increase the density, biomass, or growth rates of age-0 Arctic grayling in the artificial stream as a whole. At that scale, weather conditions and a lake outlet effect strongly affected the production of Arctic grayling. We suggest that stream-scale benefits of structures may not be fully realized until more allochthonous and autochthonous organic matter is available to the benthic fauna and fish.

- 94 - Jorgensen E.E., Canfield T.j. & Kutz F.W., 2000. Restored Riparian Buffers as Tools for Ecosystem Restoration in the MAIA; Processes, Endpoints, and Measures of Success for Water, Soil, Flora, and Fauna. Environmental Monitoring and Assessment, 63(1) : 199-210.

Abstract : Riparian buffer restorations are used as management tools to produce favorable water quality impacts, moreover among the many benefits riparian buffers may provide, their application as instruments for water quality restoration rests on a relatively firm foundation of research. However, the extent to which buffers can restore riparian ecosystems; their functionality and species composition, are essentially unknown. In light of the foregoing, two broad areas of research are indicated. First, data are needed to document the relative effectiveness of riparian buffers that differ according to width, length, and plant species composition. These questions, of managing buffer dimension and species composition for functionality, are of central importance even when attenuation of nutrient and sediment loads alone are considered. Second, where ecosystem restoration is the goal, effects to in-stream and terrestrial riparian biota need to be considered. Relatedly, the effects of the restoration on the landscape need to be considered. Particularly, at what rate do the effects of the riparian buffer on in-stream water quality, biota, and habitat diminish downstream from restored sites? Answers to these important questions are needed, for streams and watersheds of different size and for areas of differing soil type within watersheds. U.S. EPA-NRMRL has initiated as research project that will document the potential for buffers to restore riparian ecosystems; focusing on water quality effects, but also, importantly, documenting effects on biota. While substantial riparian buffer management initiatives are already underway, the extent of landscapes that influence riparian ecosystems in the eastern United States is large; leaving ample opportunity for this suggested research to provide improved buffer designs in the future. The ultimate goal of research projects developed under this paradigm of ecosystem restoration is to develop data that are needed to implement riparian buffer restorations in the mid-Atlantic and elsewhere, especially the eastern United States.

- 95 - Jungwirth M., Moog O. & Muhar S., 1993. Effects of river bed restructuring on fish and benthos of a fifth order stream, melk, Austria. Regulated Rivers: Research & Management, 8(1-2) : 195-204.

Keywords : Austria • fish • benthic invertebrates • drift restoration.

Abstract : Studies conducted on 15 sections of seven different epipotamal streams between 1981 and 1984 established the impact of river bed structures on fish communities. Reduced spatial heterogeneity due to river straightening resulted in decreasing numbers of fish species, stock density and biomass. The variance of maximum depths (VMD) used as a measure of habitat structure showed a highly significant correlation with the number (NFS) and diversity of fish species (DFS). In 1987 these models were used for the evaluation of a planned restructuring project on a channelized section of the Melk River, which was realized in 1988. During a three year investigation of the response of the fish fauna and benthic community to changed hydraulic and morphometric conditions within the restructured river bed section the validity of the VMD/NFS model could be verified. The number of fish species increased from 10 to 19. Fish density and biomass as well as annual production of 0+ fish increased three-fold. In contrast the DFS did not reach expectations, suggesting that more time is needed to establish a balanced fish community. The newly created riparian zones (e.g. shallow water lagoons, pioneer vegetation of gravel banks, etc.) provided important refuge regions during flooding, places for hatching or emerging, and nursery grounds for younger benthic instars and fish fry, indicating the positive effects of a complex water-land ecotone. Owing to the increasing habitat variability, including riffle-pool sequences, more and diverse specific benthic communities with many epipotamalic species developed. The number of benthic invertebrate taxa increased from 202 in the channelized section to 273 in the restructured area (in total 347 taxa were recorded). The benthic drift decreased significantly in the restructured river section, suggesting unfavourable conditions for many benthic invertebrates in the straightened section. Terrestrial invertebrates, however, occasionally entering the water body, showed a ten-fold increase in drift in the channelized reaches.

- 96 - Jungwirth M., Muhar S. & Schmutz S., 1995. The effects of recreated instream and ecotone structures on the fish fauna of an epipotamal river. Hydrobiologia, 303(1-3) : 195-206.

Keywords : river restoration • instream structures • land/water ecotone • fish fauna.

Abstract : Investigations of fifteen sections of seven Austrian epipotamal (barbel region) streams between 1981 and 1984 demonstrate the impact of instream river bed structures on fish communities. Reduced spatial heterogeneity due to river straightening resulted in decreasing species number, diversity, stock density and biomass. Reincreased variability of the river bed in the frame of a subsequent restructuring project improved all community-specific values significantly within a 3-year investigation period (1988–1990). Besides the regained habitat variability in form of riffle pool sequences and other instream structures, the newly created riparian zones obviously provided important niches, e.g. as refuge areas during flooding and as nursery grounds for fish fry. The positive effects of the recreated land/water ecotone are discussed with respect to river restoration projects.

- 97 - Kail J. & Hering D., 2005. Using Large Wood to Restore Streams in Central Europe: Potential use and Likely Effects. Landscape Ecology, 20(6) : 755-772.

Keywords : Central Europe • large wood • stream restoration • Water Framework Directive.

Abstract : The potentials for the use of large wood (LW) in stream restoration projects were quantified for streams in Central Europe (total stream length assessed 44,880 km). Two different restoration methods were investigated: recruitment (passively allowing natural LW input) and placement (active introduction of large wood pieces into streams). The feasibility and potential effects of each method were studied for three different scenarios, according to the land-uses to be permitted on the floodplain: (a) only natural-non woody vegetation, forest, and fallow land occur on the floodplain, (b) including pasture and meadow, (c) including pasture, meadow, and cropland. Hydromorphological data were used to identify stream sections where LW recruitment or placement are feasible, and the likely effects of both restoration methods on channel hydromorphology were predicted. Passive recruitment is feasible for only a small percentage of the total channel length in the study area (~1% for all three scenarios). Active placement of LW can be used in much higher extent: 6.5% if only natural non-woody vegetation, forest, and fallow land can occur on the floodplain, 20.2% if stream segments bordered by pasture and meadow are included, and 32% if cropland is included in addition. There are differences between (1) the lower-mountainous area, where a large number of channel segments can be restored yielding an improvement from a moderate/good to a good/excellent morphological status and (2) the lowlands, where only a small number of channel segments can be restored yielding an improvement from a bad to a moderate morphological state. The latter upgrading might be sufficient to reach a 'good ecological status' as defined by the EU Water Framework Directive. The results of this study show the suitability of large wood recruitment and placement as appropriate methods to markedly improve the hydromorphological state of a large proportion of the streams in the study area.

- 98 - Kail J., Hering D., Muhar S., Gerhard M. & Preis S., 2007. The use of large wood in stream restoration: experiences from 50 projects in Germany and Austria. Journal of Applied Ecology, 44(6) : 1145–1155

1- Wood is increasingly used in restoration projects to improve the hydromorphological and ecological status of streams and rivers. However, despite their growing importance, only a few of these projects are described in the open literature. To aid practitioners, we conducted a postal mail survey to summarize the experiences gained in central Europe and compile data on 50 projects.
2- Our results indicated the potential for improvement from an ecological point of view, as the number and total wood volume, and the median volume of single wood structures placed in the streams per project, were low compared with the potential natural state. Moreover, many wood structures were placed nearly parallel to the water flow, reducing their beneficial effect on stream hydraulics and morphology.
3- Restoration success has been monitored in only 58% of the projects. General conclusions drawn include the following. (i) The potential effects of wood placement must be evaluated within a watershed and reach-scale context. (ii) Wood measures are most successful if they mimic natural wood. (iii) Effects of wood structures on stream morphology are strongly dependent on conditions

such as stream size and hydrology. (iv) Wood placement has positive effects on several fish species. (v) Most projects revealed a rapid improvement of the hydromorphological status.

4- Most of the wood structures have been fixed, called 'hard engineering'. However, soft engineering methods (use of non-fixed wood structures) are known to result in more natural channel features for individual stream types, sizes and sites, and are significantly more cost-effective.

5- *Synthesis and applications.* Large wood has been used successfully in several projects in central Europe, predominantly to increase the general structural complexity using fixed wood structures. Our results recommend the use of less costly soft engineering techniques (non-fixed wood structures), higher amounts of wood, larger wood structures and improved monitoring programmes for future restoration projects comparable with those in this study. We recommend the use of 'passive restoration' methods (restoring the process of wood recruitment on large scales) rather than 'active restoration' (placement of wood structures on a reach scale), as passive restoration avoids the risk of non-natural amounts or diversity of wood loading developing within streams. Local, active placement of wood structures must be considered as an interim measure until passive restoration methods have increased recruitment sufficiently.

- 99 - Katz S.L., Barnas K., Hicks R., Cowen J. & Jenkinson R., 2007. Freshwater Habitat Restoration Actions in the Pacific Northwest: A Decade's Investment in Habitat Improvement. Restoration Ecology, 15(3) : 494–505.

Abstract : Across the Pacific Northwest (PNW), both public and private agents are working to improve riverine habitat for a variety of reasons, including improving conditions for threatened and endangered salmon. These projects are moving forward with little or no knowledge of specific linkages between restoration actions and the responses of target species. Targeted effectiveness monitoring of these actions is required to redress this lack of mechanistic understanding, but such monitoring depends on detailed restoration information—that is, implementation monitoring. This article describes the process of assembling a database of restoration projects intended to improve stream and river habitat throughout the PNW. We designed the database specifically to address the needs of regional monitoring programs that evaluate the effectiveness of restoration actions. The database currently contains spatially referenced, project-level data on over 23,000 restoration actions initiated at over 35,000 locations in the last 15 years (98% of projects report start or end dates between 1991 and 2005) in the states of Washington, Oregon, Idaho, and Montana. Data sources included federal, state, local, nongovernmental organization, and tribal contributors. The process of database production identified difficulties in the design of regional project tracking systems. The technical design issues range from low-level information such as what defines a project or a location to high-level issues that include data validation and legalities of interagency data sharing. The completed database will inform efficient monitoring design, effectiveness assessments, and restoration project planning.

- 100 - Kauffman J.B., Beschta R.L., Otting N. & Lytjen D., 1997. An Ecological Perspective of Riparian and Stream Restoration in the Western United States. Fisheries 22(5) : 12-24.

Abstract : There is an unprecedented need to preserve and restore aquatic and riparian biological diversity before extinction eliminates the opportunity. *Ecological restoration* is the reestablishment of processes, functions, and related biological, chemical, and physical linkages between the aquatic and associated riparian ecosystems; it is the repairing of damage caused by human activities. The first and most critical step in ecological restoration is *passive restoration*, the cessation of those anthropogenic activities that are causing degradation or preventing recovery. Given the capacity of riparian ecosystems to naturally recover, often this is all that is needed to achieve successful restoration. Prior to implementation of active restoration approaches (e.g., instream structures, channel and streambank reconfiguration, and planting programs), a period of time sufficient for natural recovery is recommended. Unfortunately, structural additions and active manipulations are frequently undertaken without halting degrading land use activities or allowing sufficient time for natural recovery to occur. These scenarios represent a misinterpretation of ecosystem needs, can exacerbate the degree of degradation, and can cause further difficulties in restoration. Restoration should be undertaken at the watershed or landscape scale. Riparian and stream ecosystems have largely been degraded by ecosystemwide, off-channel activities and, therefore, cannot be restored by focusing solely on manipulations within the channel. While ecological restoration comes at a high cost, it also is an

investment in the natural capital of riparian and aquatic systems and the environmental wealth of the nation.

- 101 - Kelly F.L. & Bracken J.J., 1998. Fisheries enhancement of the Rye Water, a lowland river in Ireland. Aquatic Conservation: Marine and Freshwater Ecosystems, 8(1) : 131-143.

Keywords : brown trout • arterial drainage • fisheries enhancement • deflectors • riprap.

Abstract :

1- The Rye Water is the major salmon spawning tributary of the River Liffey. It is an example of a lowland river which lost much of its productivity as a salmonid river following an arterial drainage scheme which extended over 2 years (1955-1957). The scheme introduced a series of hydraulically uniform continuous glides of abnormal length and a reduction in the diversity of the natural riverine habitats. To rectify this, a fisheries enhancement programme was initiated in 1994 on a 2.4 km stretch of the river.

2- The aims of the programme were to optimize the capacity of the channel to function as a brown trout (*Salmo trutta* L.) fishery, to improve the angling value of the river and to ensure that its role as a salmonid spawning and nursery area would be enhanced.

3- The enhancement project was designed to narrow and deepen the channel, create meanders, pools, cover, and to stabilize eroding stream banks. Habitat improvement structures included deflectors, riprap and boulder placements. Work was carried out by the Office of Public works in conjunction with the Central Fisheries Board and the Zoology Department, University College Dublin, Ireland.

4- Detailed monitoring of physical characteristics is continuing. Salmonid populations have been monitored by electrofishing before and after enhancement at control (unaltered areas) and experimental sections. Initial results (i.e. 1 year post-works) indicate that salmon densities have significantly increased. Brown trout, on the other hand, were slower to recover.

- 102 - Kershner L., 1997. Setting Riparian/Aquatic Restoration Objectives within a Watershed Context. Restoration Ecology, 5(4s) : 15–24.

Abstract : Declines in native plant and animal communities have prompted new interest in the restoration of aquatic and riparian ecosystems. Past restoration activities typically have been site specific, with little thought to processes operating at larger scales. A watershed analysis process developed in the Pacific Northwest identifies four operating scales useful in developing restoration priorities: region, basin, watershed, and specific site. Watershed analysis provides a template for restoration practitioners to use in prioritizing restoration activities. The template identifies seven key steps necessary to understand and develop restoration priorities: (1) characterization, (2) identification of key issues and questions, (3) documentation of current conditions, (4) description of reference conditions, (5) identification of objectives, (6) summary of conditions and determination of causes, and (7) recommendations. When a similar process was used in the Uinta Mountains, Utah, and in the Siuslaw National Forest, Oregon, specialists were able to identify key habitat conditions and habitat forming processes and then to establish restoration priorities and implement the appropriate activities. Watershed analysis provides a valuable set of tools for identifying restoration activities and is currently being used throughout the Pacific Northwest to develop management strategies and restoration priorities. Although the analysis requires significant time, money, and personnel, experience suggests that watershed analysis provides valuable direction for managing aquatic and riparian resources.

- 103 - Klassen H.D. & Northcote T.G., 1986. Stream bed configuration and stability following gabion weir placement to enhance salmonid production in a logged watershed subject to debris torrents. Canadian journal of forest research, 16(2) : 197–203.

Abstract: Tandem V-shaped gabion weirs for improving spawning habitat for salmon (*Oncorhynchus* spp.) were installed to replace large organic debris at three sites below the terminus of a debris torrent in Sachs Creek, Queen Charlotte Islands. Stream conditions were compared between gabion and nearby control sites. The stability of added and entrapped gravel at all gabion sites was poor over the first winter and excessive scour threatened the integrity of the upstream steeper (3%) slope gabion

site. However, the two gabion sites at a lower (1%) slope successfully stabilized spawning gravel in the 2nd year after installation, probably through a reduction in the local slope gradient and self-armouring of the high flow channels. Higher summer densities of juvenile coho salmon (*Oncorhynchuskisutch* (Walbaum)) and steelhead trout (*Salmogairdneri* Richardson) were recorded at the gabion sites (means, 1.2 and 0.33/m^2, respectively) compared with the control sites (means, 0.89 and 0.10/m^2). Underyearling coho fry were also significantly larger ($p < 0.05$) at gabion sites (mean, 50 mm) than at control sites (mean, 45 mm). Improved rearing habitat was created for coho juveniles by the gabions, a result of increased pool area and cover.

Résumé : Une paire de gabions en forme de V et faisant fonction de seuils ont été installés sur trois sites, en remplacement de débris organiques de grandes dimensions, afin d'améliorer les frayères à saumon (*Oncorhynchus* spp.). Les trois sites sont localisés en aval de la langue de débris torrentiels dans le ruisseau Sachs sur les îles de la Reine-Charlotte. Les conditions du lit du ruisseau ont été comparées entre les sites témoins et avec gabions. Le gravier nouvellement accumulé par les gabions était instable durant le premier hiver, ce qui a causé un affouillement excessif mettant en danger l'équilibre du site amont (gabions) dont la pente est la plus élevée (3%). Cependant, les gabions aux deux autres sites à pente plus faible (1%) ont maintenu l'équilibre des lits de fraie durant la deuxième année suivant leurs installations, probablement en partie par la diminution de la pente locale. Durant l'été on a enregistré, au stade juvénile, une plus grande densité de saumon (*O. kisutch* (Walbaum)) et de truite (*Salmogairdneri* Richardson) aux sites avec gabions (moyenne, 1,2 et 0,33/m^2, respectivement) qu'aux sites témoins (moyenne, 0,89 et 0,10/m^2). Les alevins de coho, de moins de 1 an, étaient significativement ($p < 0,05$) plus grand aux sites avec gabions (moyenne, 50 mm) qu'aux sites témoins (moyenne, 45 mm). Les gabions ont amélioré l'habitat d'élevage des saumons juvéniles en augmentant entre autres la superficie des bassins.

- 104 - Klassen H.D. & Northcote T.G., 1988. Use of Gabion Weirs to Improve Spawning Habitat for Pink Salmon in a Small Logged Watershed. North American Journal of Fisheries Management, 8(1) : 36-44.

Abstract : Tandem V-shaped gabion weirs for improving spawning habitat for Pacific salmon *Oncorhynchus* spp. were installed to replace large organic debris at three sites in Sachs Creek, Queen Charlotte Islands, British Columbia. Intragravel conditions were compared between three gabion weir pairs and six nearby reference sites. Survival of eggs of pink salmon *O. gorbuscha* was compared between one gabion pair and two reference sites. The improvement in intragravel dissolved oxygen depression (surface – intragravel concentrations) after gabion installation (a decrease from 5.4 mg/L before to 2.5 mg/L after installation) was significant ($P < 0.05$) when compared to changes found at nearby reference sites. Intragravel permeability also improved significantly ($P < 0.05$) after gabion installation in the low-gradient (1%) reaches of Sachs Creek (from 870 cm/h before to 2,400 cm/h after installation). Pink salmon egg survival calculated by two indices at one gabion site in its first year of operation did not differ significantly ($P > 0.05$) from survival at two nearby reference sites. Gabions appear to be useful tools for the restoration of damaged streams.

- 105 - Klein L.R., Clayton S.R., Alldredge J.R. & Goodwin P., 2007. Long-Term Monitoring and Evaluation of the Lower Red River Meadow Restoration Project, Idaho, U.S.A. Restoration Ecology, 15(2) : 223–239.

Abstract : Although public and financial support for stream restoration projects is increasing, long-term monitoring and reporting of project successes and failures are limited. We present the initial results of a long-term monitoring program for the Lower Red River Meadow Restoration Project in north-central Idaho, U.S.A. We evaluate a natural channel design's effectiveness in shifting a degraded stream ecosystem onto a path of ecological recovery. Field monitoring and hydrodynamic modeling are used to quantify post-restoration changes in 17 physical and biological performance indicators. Statistical and ecological significance are evaluated within a framework of clear objectives, expected responses (ecological hypotheses), and performance criteria (reference conditions) to assess post-restoration changes away from pre-restoration conditions. Compared to pre-restoration conditions, we observed ecosystem improvements in channel sinuosity, slope, depth, and water surface elevation; quantity, quality, and diversity of in-stream habitat and spawning substrate; and bird population numbers and diversity. Modeling documented the potential for enhanced river–floodplain

connectivity. Failure to detect either statistically or ecologically significant change in groundwater depth, stream temperature, native riparian cover, and salmonid density is due to a combination of small sample sizes, high interannual variability, external influences, and the early stages of recovery. Unexpected decreases in native riparian cover led to implementation of adaptive management strategies. Challenges included those common to most project-level monitoring—isolating restoration effects in complex ecosystems, securing long-term funding, and implementing scientifically rigorous experimental designs. Continued monitoring and adaptive management that support the establishment of mature and dense riparian shrub communities are crucial to overall success of the project.

- 106 - Keith R.M., Bjornn T.C., Meehan W.R., Hetrick N.J. & Brusven M.A., 1998. Response of Juvenile Salmonids to Riparian and Instream Cover Modifications in Small Streams Flowing through Second-Growth Forests of Southeast Alaska. Transactions of the American Fisheries Society, 127(6) : 889-907.

Abstract : We manipulated the canopy of second-growth red alder *Alnus rubra* and instream cover to assess the effects on abundance of juvenile salmonids in small streams of Prince of Wales Island, southeast Alaska, in 1988 and 1989. Sections of red alder canopy were removed to compare responses of salmonids to open- and closed-canopy sections. At the start of the study, all potential instream cover was removed from the study pools. Alder brush bundles were then placed in half the pools to test the response of juvenile salmonids to the addition of instream cover. Abundance of age-0 coho salmon *Oncorhynchus kisutch* decreased in both open- and closed-canopy sections during both summers, but abundance decreased at a higher rate in closed-canopy sections. More age-0 Dolly Varden *Salvelinus malma* were found in open-canopy sections than in closed-canopy during both summers. Numbers of age-1 and older coho salmon and Dolly Varden were relatively constant during both summers, and there was no significant difference in abundance detected between open- and closed-canopy sections. Abundance of age-0 coho salmon decreased in pools with and without additional instream cover during both summers. Abundance of age-1 and older coho salmon and age-0 Dolly Varden did not differ significantly in pools with or without added cover during either summer. Abundance of age-1 and older Dolly Varden was higher in pools with added instream cover than in pools without cover during both summers. Age-0 coho salmon decreased in abundance throughout the summer in both years. Emigration was measured in 1989 and accounted for most of the decrease in abundance. Age-0 coho salmon emigrants were significantly smaller than age-0 coho salmon that remained in the stream.

- 107 - Kondolf G.M., 1995. Five Elements for Effective Evaluation of Stream Restoration. Restoration Ecology, 3(2) : 133-136.

Abstract : River and stream restoration projects are increasingly numerous but rarely subjected to systematic post-project evaluation. The few such evaluation studies conducted have indicated a high percentage of failures. Thus, post-project evaluation (and dissemination of results) is essential if the field of river restoration is to advance. Effective evaluation of project success should include: (1) *Clear objectives*, essential to identity potential incompatibilities among project objectives and to provide a framework for design of project evaluation. (2) *Baseline data*, needed as an objective basis for evaluating change caused by the project and encompassing as long a pre-project period as possible (including a detailed historical study). (3) *Good study design*, to demonstrate the effects of restoration projects in the complex riverine environment. (4) *Commitment to the long term*, to detect effects evident only years following project completion; in general, monitoring should continue for at least a decade, with surveys conducted after each flood above a predetermined threshold. (5) *Willingness to acknowledge failures*, or rather to recognize that each restoration project constitutes an experiment, so that a failure can be just as valuable to the science as a success, provided we can learn from it (which requires objective, robust post-project evaluation).

- 108 - Kondolf G.M. & Micheli E.R., 1995. Evaluating stream restoration projects. Environmental Management, 19(1) : 1-15.

Key Words : stream restoration • riparian vegetation • flood control • aquatic habitat.

Abstract : River and stream restoration projects are increasingly numerous but rarely subjected to systematic postproject evaluation. Without conducting such evaluation and widely disseminating the results, lessons will not be learned from successes and failures, and the field of river restoration cannot advance. Postproject evaluation must be incorporated into the initial design of each project, with the choice of evaluation technique based directly upon the specific project goals against which performance will be evaluated. We emphasize measurement of geomorphic characteristics, as these constitute the physical framework supporting riparian and aquatic ecosystems. Techniques for evaluating other components are briefly discussed, especially as they relate to geomorphic variables. Where possible, geomorphic, hydrologic, and ecological variables should be measured along the same transects. In general, postproject monitoring should continue for at least a decade, with surveys conducted after each flood above a predetermined threshold. Project design should be preceded by a historical study documenting former channel conditions to provide insights into the processes suggest earlier, potentially stable channel configurations as possible design models.

- 109 - Kondolf G.M., 1996. A cross section of stream channel restoration. Journal of Soil and Water Conservation, 51(2) : 119-125.

Abstract : Interest in restoration of ecological, aesthetic, and recreational values to degraded stream channels has grown enormously in recent years, as has interest in developing flood control strategies that retain ecological values and avoid concrete channelization (Evans 1991; NRC 1992; Williams 1990). The term "stream (or river) restoration" is frequently used to encompass all such efforts at ecologically sound river management, even though some of these projects do not actually involve restoration of ecologically degraded channels, but rather attempt to minimize the negative environmental effects of channel relocation or flood management works. Stream "restoration" in the latter sense has also been termed stream "renovation," "reclamation," or "rehabilitation" (Nunnally 1976; Ferguson 1991; Kern 1992). The purpose of this paper is to review a range of stream restoration project goals and activities carried out in North America and Europe, to present two case studies illustrating contrasting goals and techniques, and to demonstrate the need for systematic studies evaluating the success of restoration projects.

- 110 - Kondolf G.M., Vick J.C. & Ramirez T.M., 1996. Salmon Spawning Habitat Rehabilitation on the Merced River, California: An Evaluation of Project Planning and Performance. Transactions of the American Fisheries Society, 125(6), 899-912.

Abstract : From 1986 to 1995, over US$2.5 million has been spent or allocated for projects to modify channel conditions to improve spawning habitat for Chinook salmon *Oncorhynchus tshawytscha* in the Merced, Tuolumne, and Stanislaus rivers, tributaries to the San Joaquin River, California. We evaluated the planning, design and performance of the Riffle 1 B reconstruction on the Merced River. This is typical of the nine individual riffle reconstructions completed to date, involving excavation of the existing channel bed (here, to 0.6 m) and back-filling with smaller gravels believed to be more suitable for salmon spawning. We reviewed project documents, interviewed agency staff, and conducted field surveys to document channel conditions in 1994 for comparison with the project as constructed in 1990. The project planning and design did not consider the site's geomorphic context nor processes of erosion and sediment transport under the current flow regime. As a consequence, spawning-sized gravel placed in the channel was scoured and transported through the site at a flow with a return period of 1.5 years. The need for spawning habitat enhancement in the Merced River is questionable, but if such projects are to be built, we recommend that the project planning and design consider the site's geomorphic context and acknowledge the need for and provide funds for project maintenance, and that the performance of completed projects be systematically monitored and evaluated.

- 111 - Kondolf G.M., 1998. Lessons learned from river restoration projects in California. Aquatic Conservation: Marine and Freshwater Ecosystems, 8(1) : 39-52.

Keywords : river restoration • California • effects of dams • episodic flow • flushing flows • performance evaluation.

Abstract :

1- California is a tectonically active region with a Mediterranean climate, resulting in extreme spatial and temporal variability in river channel conditions. Restoration approaches that work in one part of the state may not succeed elsewhere.
2- Restoration projects should be planned and designed based on an understanding of geomorphological and ecological *processes*, rather than simply mimicry of *form*, as in blind application of a classification scheme.
3- Most rivers in California have been dammed, resulting in changed flow and sediment transport conditions downstream. If these changes are not recognized, restoration designs are likely to be ineffective or inappropriate.
4- Very few restoration projects in California have been subject to objective post-project evaluation. As a result, opportunities to learn from past experience to improve future project design have been lost.
5- A case study on Rush Creek illustrates the importance of geomorphologically and ecologically informed project objectives, and the need to account for dam-induced hydrologic changes in developing recommendations for flushing flows.

- 112 - Kondolf G.M. & Larson M., 2006. Historical channel analysis and its application to riparian and aquatic habitat restoration. Aquatic Conservation: Marine and Freshwater Ecosystems, 5(2) : 109-126.

Abstract :

1- The planning, design and evaluation of a restoration project should be guided largely by an understanding of past channel changes.
2- A historical analysis can sometimes reveal underlying causes of channel change and document prior habitat conditions, both useful in setting appropriate objectives for restoration.
3- Restoration planning should address the historical causes and patterns of channel degradation that cannot be detected by examining current conditions alone. Moreover, ongoing adjustments in the channel and changes in the catchment must be understood when interpreting channel changes following construction of restoration projects.
4- Changes in channel form (and the independent geomorphological variables of run-off and sediment load from the catchment) can be documented from a variety of sources, including historical maps, boundary lines, aerial photography, bridge and pipeline surveys, gauging records, field evidence and archival sources. Historical riparian vegetation, and use by fish and wildlife, may also be documented from early survey records, photographs and written accounts.
5- Historical analysis should cover an area large enough to capture all events potentially influencing the project reach. The entire catchment upstream should be examined to identify events affecting the flow regime and sediment load, such as deforestation or dam construction. For channels in erodible alluvium, the study should include the channel downstream to the first stable grade control to capture events whose effects may propagate upstream, such as channelization or base lowering.
6- Application of historical channel analysis to the San Luis Rey River in California served as a basis for evaluating the potential for (and hydrological constraints upon) riparian restoration.

- 113 - Kondolf G.M., Anderson S., Lave R., Pagano L., Merenlender A. & Bernhardt E.S., 2007. Two Decades of River Restoration in California: What Can We Learn? Restoration Ecology, 15(3) : 516–523.

Abstract : As part of the National River Restoration Science Synthesis (NRRSS), we developed a summary database of 4,023 stream restoration projects built in California since 1980, from which we randomly selected 44 records for in-depth interviews with project managers. Despite substantial difficulties in gathering the data, we were able to draw conclusions about current design,

implementation, monitoring, and evaluation practices used in California projects and compare them with national trends. Although more than half of the projects for which we conducted interviews were located in watersheds for which a management or assessment plan had been prepared, these plans had a limited impact on site selection. We also found that the state lacks a consistent framework for design, monitoring, and reporting restoration projects, and that although monitoring is far more widespread than the information in the NRRSS summary database would suggest, there are still problems with the type, duration, and reporting of monitoring. The general lack of systematic, objective assessment of completed projects hinders the advance of restoration science.

- 114 - Kronvang B., Svendsen L.M., Brookes A., Fisher K., Møller B., Ottosen O., Newson M. & Sear D., 1998. Restoration of the rivers Brede, Cole and Skerne: a joint Danish and British EU-LIFE demonstration project, III - channel morphology, hydrodynamics and transport of sediment and nutrients. Aquatic Conservation: Marine and Freshwater Ecosystems, 8(1) : 209-222.

Keywords : river restoration • physical habitats • flooding • overbank sedimentation.

Abstract :

1. A comprehensive monitoring programme was initiated for the Brede, Cole and Skerne river restoration projects in order to elucidate the impact of re-meandering on flood levels, floodplain inundation, adjustment of river morphology, sediment transport and overbank sediment deposition.
2. Reducing the bankfull capacity, raising the bed level and lowering the bank level allowed an increase in flooding frequency and in the amount of water passing onto the floodplain in all three rivers. In the river Brede, restoration of the natural hydrological contact between the river and its floodplain resulted in high deposition of sediment (189 t $year^{-1}$) and sediment-associated phosphorus (770 kg P $year^{-1}$).
3. Construction work caused excessive downstream loss of sediment and phosphorus as documented from sediment mass balances for the River Brede and River Cole. Short-term adjustments in river morphology were recorded in the River Cole based on the fluvial auditing procedure. Post-restoration morphology changed compared with that before restoration in terms of both total diversity and the type of features recorded.

- 115 - Korsu K., 2004. Response of Benthic Invertebrates to Disturbance From Stream Restoration: The Importance of Bryophytes. Hydrobiologia, 523(1-3) : 37-45.

Keywords : stream restoration • benthic macroinvertebrates • disturbance • recovery • refugium • bryophytes.

Abstract : The response of benthic invertebrates to disturbance from stream restoration was studied in the Reinikankoski rapids, central Finland. I hypothesized that stream bryophytes could act as a refugium for invertebrates. The restoration procedure destroyed nearly half of the bryophytes present at the study reach, and invertebrate densities decreased sharply immediately after the restoration. Within 2 weeks, invertebrates had recolonized the disturbed reach, and within 1 month peak numbers were attained. Invertebrates showed a clear association with bryophytes, especially after the restoration. My study shows that invertebrate recovery can be relatively fast in winter, and underlines the importance of stream mosses as invertebrate habitat and refugia. They should be taken in consideration in stream restoration projects by leaving patches of stream bottom intact.

- 116 - Laasonen P., Muotka T. & Kivijärvi I., 1998. Recovery of macroinvertebrate communities from stream habitat restoration. Aquatic Conservation: Marine and Freshwater Ecosystems, 8(1) : 101-113.

Keywords : macroinvertebrate communities • habitat restoration • channelization.

Abstract :

1- Many streams channelized for timber floating in Finland are now being restored to their original condition. The most frequently used restoration structures are boulder dams, flow deflectors, excavations and channel enlargements. By increasing substrate heterogeneity and leaf litter retention, restoration may enhance the formation of detritivore-dominated macroinvertebrate assemblages. In this study, macroinvertebrate communities in streams with differing recovery periods (from 0 to 16 years) from restoration, were compared with those in channelized and near-pristine streams.

2- Water depth and current velocity were lower, and relative bed roughness higher in restored than in dredged channels. Moss cover was negligibly low in recently restored streams, but mosses had recovered well within three years from restoration. The standing stock of leaf litter was lower than in natural streams, but in most cases higher than in channelized streams.

3- Abundances of all invertebrates were highest in natural streams and lowest in streams restored 1 month before sampling. All other restored streams had abundances comparable to, or slightly lower than, those in channelized streams. There was a tendency toward higher abundances of shredders with a long recovery period, but streams restored 8 or 16 years ago still contained relatively sparse shredder populations.

4- Canonical Correspondence Analysis of the October data could be attributed to among-site variation in habitat hydraulics, moss cover and leaf litter. Dredged channels with high velocities and low bed profiles, and natural streams with high retention efficiency were the end points of this gradient. There was little indication of macroinvertebrate assemblages approaching pristine conditions with a longer recovery period.

5- Enhanced litter retention increases the capacity of restored streams to support high abundances of detritivorous invertebrates. Indirectly, restoration may also benefit animals that are not dependent on detrital food. Clearly, macroinvertebrates and other non-vertebrate components of the stream biota should be given a higher priority in the design and execution of stream restoration programmes.

- 117 - Lacey R.W.J. & Millar R.G., 2004. Reach scale hydraulic assessment of instream salmonid habitat restoration. Journal of the American Water Resources Association, 40 Issue 6 Page 1631-1644.

Abstract : This study investigates the use of a two-dimensional hydrodynamic model (River2D) for an assessment of the effects of instream large woody debris and rock groyne habitat structures. The bathymetry of a study reach (a side channel of the Chilliwack River located in southwestern British Columbia) was surveyed after the installation of 11 instream restoration structures. A digital elevation model was developed and used with a hydrodynamic model to predict local velocity, depth, scour, and habitat characteristics. The channel was resurveyed after the fall high-flow season during which a bankfull event occurred. Pre-flood and post-flood bathymetry pool distributions were compared. Measured scour was compared to predicted shear and pre-flood and post-flood fish habitat indices for coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*) were compared. Two-dimensional flow model velocity and depth predictions compare favorably to measured field values with mean standard errors of 24 percent and 6 percent, respectively, while areas of predicted high shear coincide with the newly formed pool locations. At high flows, the fish habitat index used (weighted usable area) increased by 150 percent to 210 percent. The application of the hydrodynamic model indicated a net habitat benefit from the restoration activities and provides a means of assessing and optimizing planned works.

- 118 - Lake P.S., 2005. Perturbation, Restoration and Seeking Ecological Sustainability in Australian Flowing Waters. Hydrobiologia, 552(1) : 109-120.

Keywords : disturbance • conservation • restoration • streams • rivers • Australia.

Abstract : It is now accepted that most of the rivers and streams of Australia have been degraded to varying extents by European settlement. The scale and level of this degradation have been documented by State and Federal government authorities. To halt and reverse the degradation in the next two decades, it is crucial that the conservation and restoration of streams, rivers, riparian zones, and catchments become paramount in land and water management. Effective stream restoration requires a coordinated effort at the catchment level rather than at the level of many individual local sites. Monitoring, including the gathering of before-restoration data, and the setting of feasibly-attainable goals are key components of effective restoration. In planning projects and setting goals, it needs to be recognized that some goals may only be attained in the long-term. Large-scale restoration projects will require partnerships to be formed between resource managers and scientists, with other stakeholders possibly involved. Selected projects could be adaptively managed with the emphasis on gaining scientific knowledge on the effects of management interventions.

- 119 - Lake P.S., Bond N. & Reich P., 2007. Linking ecological theory with stream restoration. Freshwater Biology, 52(4) : 597–615.

Abstract :

1- Faced with widespread degradation of riverine ecosystems, stream restoration has greatly increased. Such restoration is rarely planned and executed with inputs from ecological theory. In this paper, we seek to identify principles from ecological theory that have been, or could be, used to guide stream restoration.

2- In attempts to re-establish populations, knowledge of the species' life history, habitat template and spatio-temporal scope is critical. In many cases dispersal will be a critical process in maintaining viable populations at the landscape scale, and special attention should be given to the unique geometry of stream systems

3- One way by which organisms survive natural disturbances is by the use of refugia, many forms of which may have been lost with degradation. Restoring refugia may therefore be critical to survival of target populations, particularly in facilitating resilience to ongoing anthropogenic disturbance regimes.

4- Restoring connectivity, especially longitudinal connectivity, has been a major restoration goal. In restoring lateral connectivity there has been an increasing awareness of the riparian zone as a critical transition zone between streams and their catchments.

5- Increased knowledge of food web structure – bottom-up versus top-down control, trophic cascades and subsidies – are yet to be applied to stream restoration efforts.

6- In restoration, species are drawn from the regional species pool. Having overcome dispersal and environmental constraints (filters), species persistence may be governed by local internal dynamics, which are referred to as assembly rules.

7- While restoration projects often define goals and endpoints, the succession pathways and mechanisms (e.g. facilitation) by which these may be achieved are rarely considered. This occurs in spite of a large of body of general theory on which to draw.

8- Stream restoration has neglected ecosystem processes. The concept that increasing biodiversity increases ecosystem functioning is very relevant to stream restoration. Whether biodiversity affects ecosystem processes, such as decomposition, in streams is equivocal.

9- Considering the spatial scale of restoration projects is critical to success. Success is more likely with large-scale projects, but they will often be infeasible in terms of the available resources and conflicts of interest. Small-scale restoration may remedy specific problems. In general, restoration should occur at the appropriate spatial scale such that restoration is not reversed by the prevailing disturbance regime.

10- The effectiveness and predictability of stream ecosystem restoration will improve with an increased understanding of the processes by which ecosystems develop and are maintained. Ideas from general ecological theory can clearly be better incorporated into stream restoration projects. This will provide a twofold benefit in providing an opportunity both to improve restoration outcomes and to test ecological theory.

- 120 - Langler G.J. & Smith C., 2001. Effects of habitat enhancement on 0-group fishes in a lowland river. Regulated Rivers: Research & Management, 17(6) : 677-686.

Keywords : bays • coarse fishes • graded banks • river rehabilitation.

Abstract : Loss of habitat complexity through river channelization can have adverse affects on riverine fauna and flora through reductions in abundance and diversity of species. Habitat enhancement schemes are used to improve the physical and biological heterogeneity of riverine habitats. Between 1996 and 1997 the Environment Agency undertook a habitat enhancement scheme on the Huntspill River, Somerset, England to improve conditions for coarse (non-salmonid) fishes. The scheme involved reducing bank gradients and the construction of off-channel bays in parts of the channel, all of which were planted with willow (*Salix* sp.) and common reed (*Phragmites australis*). The effectiveness of the enhancement scheme was investigated by comparing 0-group fish assemblages in manipulated and unmanipulated sites. Abundance and diversity of 0-group fishes was significantly higher in manipulated habitats. There was no significant difference detected in the effects of the different types of enhancement measure used. The significance of microhabitats produced by habitat enhancement schemes is discussed with respect to spawning, nursery and refuge sites for 0-group coarse fish assemblages.

- 121 - Larned S.T., Suren A.M., Flanagan M., Biggs B.J.F., Riis T., 2006. Macrophytes in Urban Stream Rehabilitation: Establishment, Ecological Effects, and Public Perception. Restoration Ecology, 14 (3) : 429-440.

Abstract : Efforts to rehabilitate degraded urban streams generally focus on improving physical habitat and rarely include reestablishing biota such as macrophytes. Our objectives in this study were to propagate and transplant native macrophytes into a South Island, New Zealand, urban stream undergoing rehabilitation, assess macrophyte survival and growth, and determine whether native macrophytes suppress non-native macrophytes and/or enhance stream invertebrate communities. Effects of native macrophytes on invertebrates and non-native macrophytes were assessed after transplanting patches of native macrophytes into a 230-m-long stream section. A 100-m-long section upstream was left unplanted for subsequent comparisons. Following the study, a survey was conducted to gauge public opinion about the rehabilitation project and determine whether macrophytes were prominent in perceptions of stream health. In the first growing season, native macrophyte cover in the planted stream section increased from 1.5 to 20%, and then decreased during winter. Regrowth from rhizomes led to rapid aboveground growth during the second year, when cover reached 51%. Non-native macrophytes colonized the stream the first year, but native macrophytes appeared to limit the spread of non-natives, which were absent in the planted section by the second spring. Native macrophyte establishment did not enhance invertebrate communities as predicted; few invertebrate metrics differed significantly between the planted and unplanted sections. Pollution- and sediment-tolerant invertebrate taxa were abundant in both sections, suggesting that invertebrate colonization was limited by water quality or sedimentation, not macrophyte composition. Survey respondents considered the stream to be visually and ecologically improved after rehabilitation, and macrophyte establishment was generally considered positive or neutral.

- 122 - Larsen D.P., Kaufmann P.R., Kincaid T.M. & Urquhart N.S., 2004. Detecting persistent change in the habitat of salmon bearing streams in the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences, 61(2) : 283-291.

Abstract: In the northwestern United States, there is considerable interest in the recovery of Pacific salmon (*Oncorhynchus* spp.) populations listed as threatened or endangered. A critical component of any salmon recovery effort is the improvement of stream habitat that supports various life stages. Two factors in concert control our ability to detect consistent change in habitat conditions that could result from significant expenditures on habitat improvement: the magnitude of spatial and temporal variation and the design of the monitoring network. We summarize the important components of variation that affect trend detection and explain how well-designed networks of 30–50 sites monitored consistently over years can detect underlying changes of 1–2% per year in a variety of key habitat characteristics within 10–20 years, or sooner, if such trends are present. We emphasize the importance of the

duration of surveys for trend detection sensitivity because the power to detect trends improves substantially with the passage of years.

Résumé : On s'intéresse beaucoup, dans le nord-ouest des États-Unis, au rétablissement des populations de saumons du Pacifique (*Oncorhynchus* spp.) considérées comme menacées ou en voie de disparition. L'amélioration des habitats des cours d'eau qui abritent les différents stades du cycle des saumons est une composante essentielle de ce rétablissement. Deux facteurs associés, soit l'importance des variations spatiales et temporelles et la planification du réseau de surveillance, déterminent la capacité de détecter les changements stables de conditions de l'habitat résultant de dépenses importantes consenties pour son amélioration. Nous présentons une synthèse des principales variations qui affectent la détection des tendances, ainsi qu'une démonstration que des réseaux bien planifiés de 30–50 sites suivis constamment au cours des ans peuvent déceler des tendances sous-jacentes de 1–2 % par année pour une variété de caractéristiques fondamentales de l'habitat sur une période de 10–20 ans ou moins, lorsque de telles tendances existent. Nous insistons sur l'importance de la durée des inventaires pour la sensibilité des détections de tendances parce que la capacité de déceler les tendances s'améliore au cours des années.

- 123 - Larson M. G., Booth D.B. & Morley S.A., 2001. Effectiveness of large woody debris in stream rehabilitation projects in urban basins. Ecological Engineering 18(2) : 211-226.

Keywords: stream restoration • urban streams • stream monitoring • large woody debris • watershed restoration • biological monitoring • invertebrate monitoring

Abstract : Urban stream rehabilitation projects commonly include log placement to establish the types of habitat features associated with large woody debris (LWD) in undisturbed streams. Six urban in-stream rehabilitation projects were examined in the Puget Sound Lowland of western Washington. Each project used in-stream log placement as the primary strategy for achieving project goals; none included systematic watershed-scale rehabilitation measures. The effectiveness of LWD in these projects was evaluated by characterizing physical stream conditions using common metrics, including LWD frequency and pool spacing, and by sampling benthic macroinvertebrates. In all project reaches where pre-project data existed, pool spacing narrowed after LWD installation. All project sites exhibited fewer pools for a given LWD loading, however, than has been reported for forested streams. In project reaches where the objective was to control downstream sedimentation, only limited success was observed. At none of the sites was there any detectable improvement in biological conditions due to the addition of LWD. Our results indicate that, although LWD projects can modestly improve physical habitat in a stream reach over a time scale of 2–10 years, they apparently do not achieve commensurate improvement in biological conditions.

- 124 - Lehane B.M., Giller P.S., O'Halloran J., Smith C. & Murphy J., 2002. Experimental provision of large woody debris in streams as a trout management technique. Aquatic Conservation: Marine and Freshwater Ecosystems, 12(3) : 289-311.

Keywords : woody debris • brown trout • physical habitat • forestry-environment interactions • stream management.

Abstract :

1- The natural stock of large woody debris (LWD) in the afforested Douglas River (Fermoy, Co. Cork) is very low relative to old-growth forests, which seems to arise from deficiency both of supply and retention. Woody debris is important to the ecology and physical structure of forest streams, so its abundance is relevant to aquatic conservation and the maintenance and size of salmonid fish stocks.

2- The physical characteristics and fish stocks of 16 contiguous segments of two 200 m stream reaches were surveyed in spring 1998 prior to the installation of 12 partially spanning debris structures on four of the segments. This study investigated the effect of debris structures on the heterogeneity of flow and substratum, and the distribution of brown trout (*Salmo trutta*), and assessed the potential use of woody debris manipulation as a tool in the management of forest streams.

3- Surveys of stream habitat conditions over a 2 year period following the installation of woody debris showed a change in stream architecture. This created more suitable habitat for trout through

development of additional pools in which beds of fine sediment developed, and constraining the main current, increasing the amount of eddies and slack water areas.

4- There were significant increases in trout density and biomass in the debris segments relative to control segments without debris dams 1 and 2 years after debris addition, although trout condition was not modified by the addition of LWD. These results suggest that the addition of woody debris offers a positive and practical management technique for enhancing fish in plantation forest streams.

- 125 - Lemly D.A. & Hilderbrand R.H., 2000. Influence of large woody debris on stream insect communities and benthic detritus. Hydrobiologia, 421(1) : 179-185.

Keywords : stream habitat management • benthic macroinvertebrates • leaf processing • particulate organic matter • energetics

Abstract : We examined the extent to which benthic detritus loadings and the functional feeding group structure of stream insect communities respond to channel modifications produced by experimental addition of large woody debris (LWD, entire logs) to Stony Creek, Virginia. Benthic detritus loadings per sample did not change after LWD additions, but large increases in pool habitats created by LWD increased net detritus by an estimated 27 kg (25%) in the 250 m of stream receiving LWD. A large increase in the proportional area of pool habitats may result in a dominance of collector-gatherers and corresponding decreases in shredders and scrapers. Functional feeding group community structure in pools was similar spatially and temporally. Riffles were spatially convergent, but differed temporally. Community structure was significantly different between pools and riffles. The results indicate possible large scale influences in overall community structure due to channel alterations by LWD, but little within-habitat change.

- 126 - Lepori F., Palm D., Brännäs E. & Malmqvist B., 2005. Does restoration of structural heterogeneity in streams enhance fish and macroinvertebrate diversity? Ecological Applications, 15(6) : 2060-2071.

Key words: benthic invertebrates • biodiversity conservation • channelization • community recovery • ecosystem rehabilitation • monitoring • rarefaction • restoration assessment • timber floating.

Abstract : Restoration schemes often rely on the assumption that enhancing habitat complexity through addition of in-stream structures such as boulders and woody debris leads to increased biodiversity, but evidence for this assumption is scarce. We compared structural heterogeneity and fish and invertebrate diversity at restored, unrestored, and reference sites on tributaries of the Ume River, northern Sweden, where several kilometers of streams have been restored from channelization through placement of boulders into the channel. Structural heterogeneity at the study sites was assessed using a contour tracer at two spatial resolutions likely to be affected by restoration. These are the patch scale (0.7 m), reflecting substratum characteristics, and the reach scale (50 m), reflecting general channel topography. Fish and invertebrate samples collected via electroshocking were used to assess taxonomic richness, taxonomic density, evenness, and assemblage composition at the study sites. Measures of structural heterogeneity were substantially higher at restored relative to channelized sites; however, components of fish and invertebrate diversity were similar between these treatments. At restored sites, measures of structural heterogeneity and fish and invertebrate diversity were consistent with, or slightly exceeded reference levels. This implies that local (patch to reach) heterogeneity did not structure fish and invertebrate assemblages in the study streams. Our results suggest that restoration might have little beneficial effect on biodiversity if the restoration schemes (and the original impact under amelioration) do not affect structural heterogeneity relevant to the target organisms.

- 127 - Lepori F.; Palm D. & Malmqvist B., 2005. Effects of stream restoration on ecosystem functioning: detritus retentiveness and decomposition. Journal of applied ecology, 42(2) : 228-238.

Keywords : water engineering • freshwater environment • channelization • detritus • rehabilitation • forests • decomposition • ecosystem functioning • ecological recovery • stream.

Abstract :

1. Increasing degradation of ecological conditions in streams because of human activities has prompted widespread restoration attempts; however, the ecological consequences of restoration remain poorly understood. We explored the effects of restoration through placement of boulders into the channel in the Ume River catchment in northern Sweden, where tributary streams were extensively channelized to facilitate the transport of timber in the 19th and early 20th centuries. Retentiveness and breakdown of coarse particulate organic matter (CPOM), two key ecological functions in low-order streams most likely to be affected by channelization, were compared between restored, channelized and unimpacted reference stream sites.
2. Artificial leaves were used to assess short-term CPOM retentiveness, while CPOM breakdown was estimated as the mass loss of alder (Alnus spp.) leaf packs placed in coarse mesh litter bags. Also, the taxonomic richness, abundance, biomass and evenness of the leaf-eating invertebrates (shredders) on the retrieved leaf material were quantified. Detailed field measurements were carried out to identify geomorphological and hydraulic controls of CPOM retentiveness and breakdown at the study sites.
3. CPOM retentiveness reflected most strongly the density of boulders and submerged woody debris at the study sites. Restored sites were on average twice as retentive as channelized sites and significantly more retentive than reference sites when discharge was controlled.
4. Current velocity at bank-full flow was the single most important predictor of CPOM mass loss, implying that mechanical fragmentation was substantial during high flows; other apparent controls of CPOM breakdown included water temperature and shredder abundance. CPOM mass loss was similar between restored and reference sites. However, breakdown was slightly faster at most channelized sites, consistent with higher hydraulic stress during high flow conditions. The shredder assemblages that colonized the litter bags were similar in richness, abundance, biomass and evenness between treatments.
5. Synthesis and applications. In channelized forest streams, low retentiveness and fast mechanical fragmentation during high flows contribute to the rapid depletion of benthic CPOM following leaf abscission in autumn, thereby weakening the heterotrophic energy pathways that probably support much of the biological production in these systems. Our results illustrate that restoration by replacement of boulders can successfully reverse these impacts of channelization and thus contribute to the efficient ecological functioning of impacted streams.

- 128 - Lepori F., Gaul D., Palm D.& Malmqvist B., 2006. Food-web responses to restoration of channel heterogeneity in boreal streams. Canadian Journal of Fisheries and Aquatic Sciences, 63(11): 2478-2486.

Abstract: We assessed the biomass and stable-isotope composition ($\delta^{13}C$ and $\delta^{15}N$) of consumers (aquatic insects and fish (*Cottus gobio*)) and potential food sources (detritus, biofilm, seston, algae, and mosses) in channelized and restored streams in Sweden, assessing the hypotheses that restoration enhances detritus storage and detritus-based secondary production. Restored sites stored more detritus than channelized sites, with differences (+5.4% on average) prominent in margins, i.e., the channel area within 1.4 m from the banks. The biomass of other resources was similar between restored and channelized sites. Most common aquatic insects, including several putative detritivores, showed $\delta^{13}C$ values indicating reliance on aquatic (probably algal) carbon sources. The insectivorous fish *Cottus gobio*, on the contrary, appeared to be more dependent on terrestrial (detrital) carbon sources. The biomass and mean $\delta^{13}C$ values of the consumers were similar between restored and channelized sites, suggesting that restoration did not increase net secondary production or the fraction of secondary production based on detritus. We concluded that the increase in detritus storage at restored sites was either insufficient to enhance detritus-based production or the consumers were not limited by the availability of detritus.

Résumé : Nous évaluons la biomasse et la composition en isotopes stables ($\delta^{13}C$ et $\delta^{15}N$) des consommateurs (insectes aquatiques et poissons (*Cottus gobio*)) et de leurs sources potentielles de nourriture (détritus, biofilm, seston, algues et mousses) dans des cours d'eau canalisés et restaurés en Suède; nous vérifion les hypothèses selon lesquelles la restauration favorise le stockage du détritus et la production secondaire à base de détritus. Les sites restaurés accumulent plus de détritus que les sites canalisés et les différences (+5,4 % en moyenne) sont plus importantes près des bords, c'est-à-dire dans le chenal dans le premier 1,4 m de la rive. La biomasse des autres ressources est semblable dans les sites canalisés et restaurés. La plupart des insectes aquatiques, y compris plusieurs détritivores présumés, ont des valeurs de $\delta^{13}C$ qui indiquent une dépendance vis-à-vis des sources aquatiques de carbone (probablement les algues). Le poisson insectivore *Cottus gobio*, au contraire, semble être plus dépendant des sources terrestres de carbone (le détritus). La biomasse et les valeurs moyennes de $\delta^{13}C$ des consommateurs sont semblables dans les sites canalisés et restaurés, ce qui semble montrer que la restauration n'augmente pas la production secondaire nette, ni la fraction de la production secondaire à base de détritus. En conclusion, l'augmentation du stockage de détritus aux sites restaurés est insuffisante pour augmenter la production secondaire à base de détritus, ou alors les consommateurs ne sont pas limités par la disponibilité du détritus.

- 129 - Linlokken A., 1997. Effects of instream habitat enhancement on fish populations of a small Norwegian stream. Nordic Journal of Freshwater Research, 73 : 50-59.

Abstract : Weirs and pools were created by using an excavator on a 200 m long experimental section in a small tributary (mean discharge 0.95 m super(3)/s) of the River Glomma in southeastern Norway. The experimental section was once dredged to facilitate timber floating. The most abundant fish species in the stream were brown trout (*Salmo trutta*), bullheads (*Cottus poecilopus*) and minnows (*Phoxinus phoxinus*). Four weirs, placed in two pairs, were constructed to create 10 m wide, 15 m long and approximately 1.5 m deep pools. Small pools, 2-3 m wide and 0.7 m deep, were distributed in the stream bed between the two pairs of weirs. The density of brown trout was annually estimated by means of the mark-recapture method for the first two years (1986-87) and by successive removal the last year before enhancement (1988) and annually during six years after the enhancement (1989-96, except in 1993-94). A reference section was sampled simultaneously, except in 1989. The mean density of brown trout on the experimental section was 18.3 per 100 m prior to enhancement, and increased by 200% after the construction of weirs. The increase was due to increased number of specimens > 10 cm, whereas number of specimens <10 cm (agegroups less than or equal to 1+) decreased. In 1996 the density was reduced close to the conditions before enhancement, and this was probably caused by a heavy flood in 1995, deteriorating the weirs followed by a cold winter with thin snow layer and a thick ice cover. Age group 2+ dominated in the pooled sample, and low representation of agegroups less than or equal to 1 + indicated that the brown trout stock on this section must be recruited by immigration from sections upstream.

- 130 - Lonzarich D.G. & Quinn T.P., 1995. Experimental evidence for the effect of depth and structure on the distribution, growth, and survival of stream fishes. Canadian Journal of Zoology/Revue Canadienne de Zoologie. Vol. 73, no. 12, pp. 2223-2230.

Abstract : Water depth and physical structure are important components of habitat complexity for stream fishes. Experiments in a semi-natural stream, containing four depth and structure treatments, quantified the effect of these two habitat components on the distribution, growth, and survival of five fish species common to coastal streams of Washington State. When fishes were permitted to move freely among the various habitat types, most species and age-classes were underrepresented in shallow pools lacking structure. In some cases water depth or physical structure alone appeared to explain these distributions. However, assemblage- and species-level responses were strongly influenced by the combined effects of depth and structure. A subsequent 30-d experiment revealed that mortality (likely due to bird predation) of water-column species using the simplest habitat type was as much as 50% greater than in the other treatments. However, there were no differences in survival of the benthic species, coastrange sculpin (*Cottus aleuticus*), among the different treatments, nor were there significant differences in growth among treatments for any species. These results indicate that predation risk may help to explain the importance of both deep water and physical structure to fishes in coastal streams in Washington. The results of our habitat-selection experiment also support the

growing view that a community-level approach may be more effective than the single-species approach in evaluating the effects of human activities on stream fishes.

- 131 - Lüderitz V., Jüpner R., Müller S. & Feld C.K., 2004. Renaturalization of streams and rivers — the special importance of integrated ecological methods in measurement of success. An example from Saxony-Anhalt (Germany). Limnologica - Ecology and Management of Inland Waters, 34(3) : 249-263.

Keywords : EU-Water Framework Directive (EU-WFD) • renaturalization • lowland stream; measurement of success • macroinvertebrates.

Abstract : Since hydromorphology in about 80% of German streams and rivers is degraded to a high degree, increased efforts in hydromorphological renaturalization are necessary. A measurement of the success of the first realized projects shows that improvement in stream morphology has a remarkably positive influence on aquatic ecology. An example of a restored stretch of a lowland stream in Saxony-Anhalt is used to describe the possibilities of success measurement programs for improvement of poor renaturalization. Therefore, a combined morphological and hydrobiological approach was developed. An integrated ecological assessment is possible by using the multimetric index EQI_M (Ecological Quality Index using benthic Macroinvertebrates) and the GFI (German Fauna Index). The latter represents a tolerance measure to evaluate the hydromorphological status of a site by using certain taxa that indicate either positive or negative physical attributes. To consider the special characteristics of the stream in its landscape unit, specific reference conditions ('Leitbild') were defined for macroinvertebrate communities by sampling comparable but undisturbed streams in the same landscape unit. Only the combination of biological indices, hydromorphological mapping and comparison to the reference status allows for an expressive evaluation of renaturalization measures and precise conclusions for their improvement.

- 132 - Mäki-Petäys A., Vehanen T. & Muotka T., 2000. Microhabitat Use by Age-0 Brown Trout and Grayling: Seasonal Responses to Streambed Restoration under Different Flows. Transactions of the American Fisheries Society, 129(3) : 771–781.

Abstract : We examined microhabitat selection by age-0 brown trout *Salmo trutta* and grayling *Thymallus thymallus* in experimental flumes with channelized (monotonic configuration and low amount of stones) or restored (highly heterogenous substrate) streambed structures at low and high flows and at different times of year. Both brown trout and grayling used higher water velocities in summer high flows. Both species also occupied higher-velocity microhabitats in channelized than in restored flumes, but for grayling this difference was significant only in summer. Overall, brown trout used lower water velocities than grayling. In winter and in high-flow treatments, brown trout were more susceptible to downstream displacement in channelized compared with restored flumes. For grayling, the effect of flume type occurred only in winter when fish were located further downstream in channelized flumes. Both species were more aggregated in winter. Brown trout also exhibited a different spatial pattern among the flume types, being more aggregated in channelized flumes. The flume type did not affect the spatial pattern of grayling, but they were more contiguously distributed in high flows. Because both brown trout and grayling used lower velocities in winter, the potential for interspecific competition may increase in winter. The spatiotemporal differences in fish habitat preferences suggest that assessment of the physical carrying capacity of a stream in relation to species-specific habitat requirements is a prerequisite for effective management of brown trout and grayling populations. Preference curves indicated that the habitat requirements were narrowest in winter and that the crucial habitat factor was the availability of flow refuges; thus, the curves helped identify the timing of, and the key factor underlying, a potential habitat bottleneck in northern boreal streams.

- 133 - Merz J.E., Setka J.D., Pasternack G.B. & Wheaton J.M., 2004. Predicting benefits of spawning-habitat rehabilitation to salmonid (*Oncorhynchus* spp.) fry production in a regulated California river. Canadian Journal of Fisheries and Aquatic Sciences, 61(8): 1433-1446.

Abstract: We tested the hypothesis that spawning-bed enhancement increases survival and growth of chinook salmon (*Oncorhynchus tshawytscha*) embryos in a regulated California stream with a gravel deficit. We also examined how 12 physical parameters correlated within spawning sites and how well they predicted survival and growth of chinook salmon and steelhead (*Oncorhynchus mykiss*) embryos. Salmon embryos planted in enhanced gravels had higher rates of survival to the swim-up stage than embryos planted in unenhanced spawning gravels. No significant increase in growth was observed. Intergravel temperature and substrate size were strongly correlated with distance downstream from the lowest nonpassable dam. Intergravel turbidity and total suspended and volatile solids were also strongly correlated. Multiple-regression models were built with a combination of physical measurements to predict survival and length of salmon and steelhead embryos. Survival models accounted for 87% of the variation around the mean for salmon and 82% for steelhead. Growth models accounted for 95% of the variation around the mean for salmon and 89% for steelhead. These findings suggest that spawning-bed enhancement can improve embryo survival in degraded habitat. Additionally, measurements of a suite of physical parameters before and after spawning-bed manipulation can accurately predict benefits to target species.

Résumé : Nous avons éprouvé l'hypothèse selon laquelle l'aménagement des sites de reproduction augmente la survie et la croissance des embryons du saumon quinnat (*Oncorhynchus tshawytscha*) dans un cours d'eau de Californie soumis à la régulation et ayant une pénurie de gravières. Nous avons aussi déterminé la corrélation entre 12 variables physiques dans les sites de fraye et examiné comment elles peuvent prédire la survie et la croissance des embryons de saumons quinnat et de truites arc-en-ciel anadromes (*Oncorhynchus mykiss*). Les oeufs de saumons insérés dans des gravières améliorées ont une meilleure survie jusqu'au stade du début de la nage que ceux qui sont mis dans des gravières de fraye non améliorées. Il n'y a pas d'accélération significative de la croissance. La température dans le gravier et la taille du substrat sont en forte corrélation avec la distance en aval du barrage infranchissable le plus en aval. La turbidité dans le gravier, les solides totaux en suspension et les solides volatils affichent aussi la même forte corrélation. L'élaboration de modèles de régression multiple basés sur une combinaison de mesures physiques permettent de prédire la survie et la longueur des embryons de saumons quinnat et de truites arc-en-ciel anadromes. Les modèles de survie expliquent 87 % de la variation autour de la moyenne chez le saumon et 82 % chez la truite. Les modèles de croissance expliquent 95 % de la variation autour de la moyenne chez le saumon et 89 % chez la truite. Ces résultats montrent que l'amélioration des sites de fraye dans les habitats dégradés peut accroître la survie des embryons. De plus, la mesure des variables physiques avant et après la manipulation des sites de fraye peut permettre de prédire les avantages escomptés pour les espèces visées par l'aménagement.

- 134 - Merz J.E. & Ochikubo Chan L.K., 2005. Effects of gravel augmentation on macroinvertebrate assemblages in a regulated California River. River Research and Applications, 21(1) : 61-74.

Keywords : river enhancement • macroinvertebrates • salmon • spawning • gravel • biomass • species diversity • physical habitat.

Abstract : Enhancement projects within anadromous salmonid rivers of California have increased in recent years. Much of this work is intended as mitigation in regulated streams where salmon and steelhead spawning habitat is inaccessible or degraded due to dams, water diversions and channelization. Little research has been done to assess the benefits of spawning habitat enhancement to stream organisms other than salmon. We monitored benthic macroinvertebrates at seven spawning gravel augmentation sites in the lower Mokelumne River, a regulated stream in the Central Valley of California. Placement of cleaned floodplain gravel decreased depths and increased stream velocities. Benthic organisms colonized new gravels quickly, equalling densities and biomass of unenhanced spawning sites within 4 weeks. Macroinvertebrate species richness equalled that of unenhanced sites within 4 weeks and diversity within 2 weeks. Standing crop, as indicated by densities and dry biomass, was significantly higher in enhancement sites after 12 weeks than in unenhanced sites and remained so over the following 10 weeks. Although mobile collector/browsers initially dominated new gravels,

sedentary collectors were the most common feeding category after 4 weeks, similar to unenhanced sites. These data suggest that cleaned gravels from adjacent floodplain materials, used to enhance salmonid spawning sites, are quickly incorporated into the stream ecosystem, benefiting benthic macroinvertebrate densities and dry biomass.

- 135 - Mesick C.F., 1995. Response of brown trout to streamflow, temperature, and habitat restoration in a degraded stream. Rivers, 5(2) : 75-95.

Abstract : In Rush Creek, California, historical dewatering, flooding, grazing, and gravel operations reduced the quantity of gravel, woody debris, and pool habitat; widened and incised the channel in the downstream reaches; and restricted the riparian vegetation to a narrow band along the stream margin. This study monitored the self-reproducing brown trout (*Salmo trutta*) population in degraded and undisturbed reaches from 1985 to 1993, primarily to determine the response to streamflow and restoration work. High streamflow in conjunction with fluctuating temperatures during winter reduced survival of juvenile trout and growth rates of all ages. Maximum summer water temperatures were also negatively correlated with growth and survival rates. Moderate summer streamflows reduced temperature fluctuations, particularly in the downstream segments, thereby improving growth and survival; however high summer flows reduced growth rates and eliminated large prey. The availability of large prey resulted in high growth and survival in spite of high summer temperatures. Survival and growth were positively correlated with the amount of pool habitat, water depth, and streambed complexity, particularly when winter flows and summer water temperatures were high. Gravel availability and young-of-the-year production increased with high flows prior to spawning. However, moderate flows mobilized instream gravel without providing gravel recruitment. Gravel added to the stream as part of restoration work increased young-of-the-year densities, particularly in the reaches where gravel was placed. Large pools excavated in the main channel that had root wads and clusters of boulders added for cover increased growth rates but did not increase survival when winter flows were high. Rewatered side channels, some with excavated pools, were utilized by few trout but increased survival and growth when winter flows were high.

- 136 - Meyer K.A. & Griffith, 1997. Effects of Cobble–Boulder Substrate Configuration on Winter Residency of Juvenile Rainbow Trout. North American Journal of Fisheries Management, 17(1) : 77-84.

Abstract : We assessed first winter habitat use by placing wild rainbow trout *Oncorhynchus mykiss* (52–155 mm total length) in wire-mesh enclosures with different cover treatments and at varying fish densities. Cobble–boulders substrates (20–40 cm diameter) were arranged in four different configurations: (1) no cobble–boulders, (2) cobble–boulders present but not touching, (3) cobble–boulders touching in a single layer, and (4) cobble–boulders touching and stacked in two layers. As the configuration of rock substrate was changed to create more concealment cover, the number of fish remaining in the enclosures after 96 h increased significantly, even though the quantity of rock substrate did not change. The initial stocking density of fish had no overall significant effect on the number of fish remaining in enclosures after 96 h. However, analysis of each cover × density treatment showed that when the substrate arrangement created little concealment cover, the number of fish remaining in the enclosures did not increase with an increase in initial fish density, but when the substrate arrangement created relatively more concealment cover, more fish remained in the enclosures when the initial fish density was increased. In trials with rock cover present, fish emigrating from the enclosures were larger than those remaining in the enclosures. Our results demonstrate the importance of the configuration of cobble–boulders substrate in determining its suitability as winter cover for rainbow trout

- 137 - Mitchell J., McKinley R.S., Power G. & Scruton D.A, 1998. Evaluation of Atlantic salmon parr responses to habitat improvement structures in an experimental channel in Newfoundland, Canada. Regulated Rivers: Research & Management, 14 (1) : 25-39.

Keywords : habitat improvement • *Salmo salar* • Newfoundland • microhabitat • distribution • food availability.

Abstract : Distributional patterns and microhabitat selection of Atlantic salmon (*Salmo salar*) parr were investigated in relation to habitat improvement structures in a controlled flow experiment channel at Noel Paul's Brook, Newfoundland. The channel consisted of six replicates, each containing three randomly arranged treatments. Each replicate included a control treatment with no habitat modification, a mid-channel treatment with a boulder cluster and low-head barrier dam, and a stream bank treatment with undercut banks and wing deflectors. The influence of size class, density, discharge and diurnal/nocturnal differences on microhabitat selection were evaluated. Results showed that the mid-channel treatment did not serve its purpose at lower discharges (0.032-0.063 $m^3 s^{-1}$), and as a result was not the treatment of choice. However, as the discharge increased (0.13 $m^3 s^{-1}$), more salmon took up residence in this treatment. In all experiments, greater depths were selected in the stream bank treatment, and salmon parr in the mid-channel treatment consistently selected positions closer to cover. Larger parr preferred greater depths and were found closer to the improvement structures. Benthic and drifting food availability were also estimated, and results showed that 'funnelling effects' of the drift were created near the structures. This study indicates that these structures have the potential to create favourable feeding sites, and provide the necessary physical characteristics required by salmon parr.

- 138 - Michener W.K., 1997. Quantitatively Evaluating Restoration Experiments: Research Design, Statistical Analysis, and Data Management Considerations. Restoration Ecology, 5(4) : 324–337.

Abstract : Conceptual and logistical challenges associated with the design and analysis of ecological restoration experiments are often viewed as being insurmountable, thereby limiting the potential value of restoration experiments as tests of ecological theory. Such research constraints are, however, not unique within the environmental sciences. Numerous natural and anthropogenic disturbances represent unplanned, uncontrollable events that cannot be replicated or studied using traditional experimental approaches and statistical analyses. A broad mix of appropriate research approaches (e.g., long-term studies, large-scale comparative studies, space-for-time substitution, modeling, and focused experimentation) and analytical tools (e.g., observational, spatial, and temporal statistics) are available and required to advance restoration ecology as a scientific discipline. In this article, research design and analytical options are described and assessed in relation to their applicability to restoration ecology. Significant research benefits may be derived from explicitly defining conceptual models and presuppositions, developing multiple working hypotheses, and developing and archiving high-quality data and metadata. Flexibility in research approaches and statistical analyses, high-quality databases, and new sampling approaches that support research at broader spatial and temporal scales are critical for enhancing ecological understanding and supporting further development of restoration ecology as a scientific discipline.

- 139 - Miller J.R. & Hobbs R.J., 2007. Habitat Restoration—Do We Know What We're Doing? Restoration Ecology, 15(3) : 382–390.

Abstract : The term "habitat restoration" appears frequently in conservation and landscape management documents but is often poorly articulated. There is a need to move to a clearer and more systematic approach to habitat restoration that considers appropriate goals linked to target species or suites of species, as well as the ecological, financial, and social constraints on what is possible. Recommendations for particular courses of action need to be prioritized so that restoration activities can achieve the best result possible within these constraints. There is unlikely to be a generic set of recommendations that is applicable everywhere because actions need to be matched to the particulars of site and situation. However, there is a generic set of questions that can be asked, which can help guide the process of deciding which restoration actions are most important and contribute most to the reestablishment of desirable habitat characteristics within a given project area.

- 140 - Minns C.K., Kelso J.R.M. & Randall R.G., 1996. Detecting the response of fish to habitat alterations in freshwater ecosystems. Canadian Journal of Fisheries and Aquatic Sciences, 53(S1): 403–414.

Résumé : Les mesures précipitées de restauration des écosystèmes d'eau douce nuisent à l'évaluation scientifique des succès et des échecs. Les écologistes qui planifient ces projets ne tiennent pas compte des connaissances actuelles sur les écosystèmes. Dans le présent article, nous examinons le problème que pose la détection des réactions des poissons aux modifications apportées à leur habitat, selon 4 points de vue interreliés : les attentes, les mesures, la variabilité et l'échelle. Les modifications d'habitat ayant pour cible les populations d'une seule espèce ont généralement un effet sur les autres composantes de l'écosystème. La communauté ichtyenne, qui comprend plus d'une espèce, sert de point de comparaison pour la détection des réactions. Un ensemble de 15 réactions possibles met en relief la nécessité d'utiliser toute une gamme d'indicateurs écologiques si on veut envisager plusieurs solutions distinctes. Nous passons en revue les mesures qui peuvent être utilisées, puis nous relevons les types et les sources de variabilité spatiale et temporelle. Les indicateurs intégrant plusieurs facteurs, comme les indices de production et de communauté, conviennent sans doute mieux à la détection des changements, car ils sont moins sujets à varier. Par ailleurs, les échelles spatiale et temporelle qui caractérisent la réaction des écosystèmes sont généralement plus grandes que celles où se font les interventions humaines et les évaluations. Nous proposons enfin des lignes directrices pour la conception des évaluations. Toute mesure d'aménagement constitue une expérience et doit à ce titre faire l'objet d'une évaluation. Le progrès des connaissances exige une observation systématique, avec répétition et témoins. Les plans de restauration doivent porter davantage sur les écosystèmes et moins sur des espèces que l'on entend privilégier. Etant donné les échelles auxquelles les expériences doivent être menées, il faut multiplier les occasions de recherche utile en élargissant la coordination, la consultation et la coopération.

- 141 - Moerke A.H., Gerard K.J., Latimore J.A., Hellenthal R.A. & Lamberti G.A., 2004. Restoration of an Indiana, USA, stream: bridging the gap between basic and applied lotic ecology. Journal of the North American Benthological Society, 23(3) : 647-660.

Keywords: stream habitat • sedimentation • biotic recovery • fish • macroinvertebrates • periphyton.

Abstract : Stream restoration attempts to reverse the global degradation of rivers and streams, but rigorous evaluations are needed to advance the science. We evaluated a 3rd-order channelized Indiana (USA) stream that was restored in 1997 by constructing two meanders, each ~ 400 m long. Pool and riffle sequences were constructed, coarse substrate and wood were added to the channel, banks were stabilized and revegetated, and sedimentation was reduced by creating a sediment retention basin upstream. Habitat, periphyton, macroinvertebrates, and fishes were measured before restoration and for 5 y after restoration in the restored reaches and in an upstream, unrestored reach. Restoration improved habitat conditions (e.g., more pools, fewer fine sediments) in both restored reaches compared to the unrestored reach. Within 1 y after restoration, major trophic groups (i.e., periphyton, macroinvertebrates, and fishes) recovered to or exceeded levels in the degraded, unrestored reach. However, biotic responses varied with time, trophic level, and community parameter measured. Five years after the restoration, habitat quality, algal abundance, and macroinvertebrate density remained higher in the restored reaches, whereas macroinvertebrate diversity and fish abundance in the restored reaches were similar to or below levels in the unrestored, channelized reach. Although biotic recovery was relatively rapid, long-term persistence is uncertain because of continued sedimentation at a watershed scale. In many instances, reach-scale restorations may be ineffective in the face of basin-wide degradation. This study illustrates the importance of conducting long-term assessments of stream restorations, which can improve both knowledge and management of stream ecosystems.

- 142 - Moerke A.H. & Lamberti G.A., 2003. Responses in Fish Community Structure to Restoration of Two Indiana Streams. North American Journal of Fisheries Management, 23(3) : 748-759.

Abstract : Stream restoration has accelerated in the Midwestern United States during the past decade, but the effects of restoration on stream biota are rarely evaluated. From 1997 to 2000, we studied the responses in fish communities to the attempted restoration of two channelized streams

(Juday Creek and Potato Creek) in northwestern Indiana, each of which received two new meanders to a 1-km reach of stream length. The restored meanders of Juday Creek also received major improvement to instream habitat, bank stabilization, and silt control. In contrast, Potato Creek received only reconnection of the stream to historical meanders. Fish were monitored for 3 years after reconstruction by use of electroshocking and salmonid redd surveys. In Juday Creek, trout size-class distribution broadened and redd construction increased in the restored reaches. However, most fish metrics for reconstructed reaches did not surpass the levels in the channelized reaches after 3 years. Continued sedimentation from upstream sources, which reduced habitat quality, likely counteracted the positive effects of the restoration. In contrast, unanticipated geomorphic changes in Potato Creek led to decreased current velocity and highly altered fish community structure. The American brook lamprey *Lampetra appendix,* a sensitive species, was not collected after restoration, and the fish community changed from rheophilic species to highly tolerant, slow-water species. Overall, changes in fish community structure revealed strengths and weaknesses in contemporary stream restoration approaches, findings that will aid future restoration efforts.

- 143 - Moerke A.H. & Lamberti G.A., 2004. Restoring Stream Ecosystems: Lessons from a Midwestern State. Restoration Ecology, 12(3) : 327–334.

Abstract : Reach-scale stream restorations are becoming a common approach to repair degraded streams, but the effectiveness of these projects is rarely evaluated or reported. We surveyed governmental, private, and nonprofit organizations in the state of Indiana to determine the frequency and nature of reach-scale stream restorations in this midwestern U.S. state. For 10 attempted restorations in Indiana, questionnaires and on-site assessments were used to better evaluate current designs for restoring stream ecosystems. At each restoration site, habitat and water quality were evaluated in restored and unrestored reaches. Our surveys identified commonalities across all restorations, including the type of restoration, project goals, structures installed, and level of monitoring conducted. In general, most restorations were described as stream-relocation projects that combined riparian and in-stream enhancements. Fewer than half of the restorations conducted pre- or post-restoration monitoring, and most monitoring involved evaluations of riparian vegetation rather than aquatic variables. On-site assessments revealed that restored reaches had significantly lower stream widths and greater depths than did upstream unrestored reaches, but riparian canopy cover often was lower in restored than in unrestored reaches. This study provides basic information on midwestern restoration strategies, which is needed to identify strengths and weaknesses in current practices and to better inform future stream restorations.

- 144 - Muhar S. , Jungwirth M., Unfer G. , Wiesner C., Poppe M., Schmutz S., Hohensinner S. & Habersack H., 2007. 30 Restoring riverine landscapes at the Drau River: successes and deficits in the context of ecological integrity. Developments in Earth Surface Processes, 11 : 779-803

Abstract : In the 19th and 20th centuries, most alluvial rivers in the northern hemisphere were severely disturbed with respect to their hydro-morphology, connectivity, and bedload and discharge regimes. In Austria the relative frequency of braided reaches declined from 28% to 1% over the last century. Thus, several recent restoration efforts have concentrated on formerly dynamic gravel-bed rivers affected by channelisation and river-bed degradation.
This paper examines the successes and constraints of selected restoration examples of different spatial extent along the Drau River, Carinthia. Both the hydro-morphological conditions and the status of the fish fauna are assessed using a 5-tiered scheme according to the EU Water Framework Directive (WFD) based on the type-specific physical environment.
The results show clear improvements of the habitat and fish ecological situation in rehabilitated sites of the Drau River. In particular, juvenile stages of the key fish species – the grayling (*Thymallus thymallus* L.) – benefit from increased areas of shallow habitats; the ecological status improved between 0.2 and 0.9 ecological classes according to the WFD, depending on the spatial extent of the measures. Despite increased efforts in habitat rehabilitation, restoration success is still limited by remaining ecological deficits, such as the disrupted longitudinal river continuum and hydro-peaking, which were not addressed in the project. The presented analyses yield a better perspective on major ecological requirements for future restoration efforts of alluvial riverine landscapes.

- 145 - Muotka T. & Laasonen P., 2002. Ecosystem Recovery in Restored Headwater Streams: The Role of Enhanced Leaf Retention. The Journal of Applied Ecology, 39(1) : 145-156.

Abstract :

1. There is controversy over how the success of ecological restoration should be measured. Traditionally, emphasis has been placed on species diversity and other community attributes, whereas the restoration of ecosystem processes has received less attention. Here, we combine replicated field experiments and a field survey to provide an ecosystem-level measure of stream restoration success.
2. Numerous headwater streams in Finland, and in many other parts of the world, have been channelized for timber transport, resulting in channels with simplified structure and flow. Recently, programmes have been launched to restore these streams to their pre-channelization condition. While the efficacy of restoration in improving fish habitat has been tested, little is known about effects on other stream biota or on the retention of leaf litter, despite its importance in trophic dynamics of forested headwater streams. Using a before-after-control-intervention (BACI) designed experiment with multiple reference and experimental streams, we examined restoration-induced changes in retention efficiency by conducting leaf-release experiments before (1993) and after (1996) restoration.
3. Substrate heterogeneity increased, but moss cover decreased dramatically following restoration. Retention efficiency in restored streams was higher than in channelized, but lower than in natural, streams. Algae-feeding scrapers were the only macroinvertebrate group whose density increased significantly after restoration.
4. Aquatic mosses were a key retentive feature in both channelized and natural streams, but their importance to retention was strikingly reduced by restoration. During restoration work, mosses are detached from large areas of the stream bed, exposing bare stone surfaces for colonization by periphytic algae.
5. A more effective restoration technique would involve the use of moss transplants, or the addition of large woody debris, to increase retentiveness and thus enhance the availability of organic material to benthic consumers. This case study on rivers illustrates how restoration projects benefit from an ecosystem perspective and from measures of ecosystem processes in assessing restoration success.

- 146 - Muotka T., Paavola R., Haapala A., Novikmec M. & Laasonen P., 2002. Long-term recovery of stream habitat structure and benthic invertebrate communities from in-stream restoration. Biological Conservation, 105(2) : 243-253.

Keywords : stream restoration • benthic invertebrates • biodiversity conservation • community recovery.

Abstract : Headwater streams channelized for water transport of timber in Finland are being restored to their pre-channelization state. The primary motivation is the enhancement of sport fisheries, but restoration probably has profound impacts also on other stream organisms. We assessed how such “single-goal” restorations affect benthic macroinvertebrate communities. We revisited the streams sampled by Laasonen et al. [Aquatic Conservation: Marine and Freshwater Ecosystems 8 (1998)] in the early 1990s when the streams had been recently restored. In 1997, the recovery period of these streams ranged from 4 to 8 years. Habitat structure among the stream types represented a distinct recovery gradient, with streams restored 1 month before sampling and natural streams being the endpoints of a gradient in moss cover (highest in natural, lowest in recently restored streams). Channelized streams supported a characteristic set of indicator species, whereas shifts in species composition between restored and natural streams were more gradual. Macroinvertebrate communities in unmodified streams changed little between the two surveys, whereas communities in restored streams had undergone considerable changes. In-stream restoration is an unpredictable disturbance, to which stream biota cannot have any evolved responses. Therefore, the relatively rapid recovery of habitat structure and macroinvertebrate communities in restored streams is encouraging. However, long-term monitoring of benthic communities in both restored and natural streams is needed to assess whether restoring rivers by these techniques will enhance the recovery of benthic biodiversity in boreal streams.

- 147 - Muotka T. & Syrjänen J., 2007. Changes in habitat structure, benthic invertebrate diversity, trout populations and ecosystem processes in restored forest streams: a boreal perspective. Freshwater Biology 52 (4), 724–737.

Abstract :

1- Most Finnish streams were channelised during the 19th and 20th century to facilitate timber floating. By the late 1970s, extensive programmes were initiated to restore these degraded streams. The responses of fish populations to restoration have been little studied, however, and monitoring of other stream biota has been negligible. In this paper, we review results from a set of studies on the effects of stream restoration on habitat structure, brown trout populations, benthic macroinvertebrates and leaf retention.

2- In general, restoration greatly increased stream bed heterogeneity. The cover of mosses in channelised streams was close to that of unmodified reference sites, but after restoration moss cover declined to one-tenth of the pre-restoration value.

3- In one stream, densities of age-0 trout were slightly lower after restoration, but the difference to an unmodified reference stream was non-significant, indicating no effect of restoration. In another stream, trout density increased after restoration, indicating a weakly positive response. The overall weak response of trout to habitat manipulations probably relates to the fact that restoration did not increase the amount of pools, a key winter habitat for salmonids.

4- Benthic invertebrate community composition was more variable in streams restored 4–6 years before sampling than in unmodified reference streams or streams restored 8 years before sampling. Channelised streams supported a distinctive set of indicator species, most of which were filter-feeders or scrapers, while most of the indicators in streams restored 8 years before sampling were shredders.

5- Leaf retentiveness in reference streams was high, with 60–70% of experimentally released leaves being retained within 50 m. Channelised streams were poorly retentive (*c.* 10% of leaves retained), and the increase in retention following restoration was modest (+14% on average). Aquatic mosses were a key retentive feature in both channelised and natural streams, but their cover was drastically reduced through restoration.

6- Mitigation of the detrimental impacts of forestry (e.g. removal of mature riparian forests) is a major challenge to the management of boreal streams. This goal cannot be achieved by focusing efforts only on restoration of physical structures in stream channels, but also requires conservation and ecologically sound management of riparian forests.

- 148 - Myers T.J. & Swanson S., 1996. Long-term aquatic habitat restoration : Mahogany creek, Nevada, as a case study. Journal of the American Water Resources Association, 32(2) : 241–252.

Abstract : We compared the recovery from abusive grazing of aquatic habitat due to different range management on two geomorphically similar rangeland streams in northwest Nevada. Managers excluded livestock from the Mahogany Creek watershed from 1976 to 1990 while allowing rotation of rest grazing on its tributary Summer Camp Creek. Bank stability, defined as the lack of apparent bank erosion or deposition, improved through the study period on both streams, but periodic grazing and flooding decreased stability more on Summer Camp Creek than flooding alone on Mahogany Creek. Pool quantity and quality on each stream decreased because of coarse woody debris removal and sediment deposition during a drought. Fine stream bottom sediments decreased five years after the removal of livestock, but sedimentation increased during low flows in both streams below road crossings. Tree cover increased 35 percent at both streams. Thus, recovery of stability and cover and decreased sedimentation are compatible with rotation of rest grazing on Summer Camp Creek. Width/depth ratio and gravel/cobble percent did not change because they are inherently stable in this stream type. Management activities such as coarse woody debris removal limited pool recover and road crossings increased sedimentation.

- 149 - Nakamura Keigo, Tockner K. & Amano K., 2006. River and wetland restoration : Lessons from Japan. BioScience 56(5) : 419-429.

Keywords : conservation • rehabilitation • biodiversity • floodplain • lake.

Abstract : River and wetland restoration has emerged as a worldwide phenomenon ans is becoming a highly profitable business. Althought researchers worldwide know a lot about restoration in Europe and the United-States, we have only scant information about the activities in Japan, where more than 23.000 river restoration projects have been conducted during the past 15 years. In Japan, restoration is a daunting business besause of the high human population density, urbanization, and harsh environmental conditions. Here we provide an overview of the varioux restoration activities in Japan and discuss the lessons that can draw from them.

- 150 - Nakano D. & Nakamura F., 2006. Responses of macroinvertebrate communities to river restoration in a channelized segment of the Shibetsu River, Northern Japan. River Research and Applications, 22(6) : 681-689.

Keywords : river restoration • reconstructed meanders • groyne structures • lowland rivers • channel straightening • macroinvertebrate community • riverbed stability.

Abstract : The effects of restoration of channel meandering and of groyne structures on physical variables and river-dwelling macroinvertebrates were examined in a lowland river, the Shibetsu River in Northern Japan. The lowland segment of the Shibetsu River, which previously meandered, was straightened by channelization and groynes installed on some portions of the channelized reach. In 2002, the channelization works were partly reversed to improve the degraded river ecosystem.
Physical environment variables and macroinvertebrate community structure and composition were compared among reconstructed meanders and channelized reaches with and without groynes. The shear stress of the river edge in reconstructed meanders and groyne reaches was lower than that in a channelized reach. In addition, the edge habitat near the stream bank created by the reconstructed meander and groyne reaches had higher total density and taxon richness of macroinvertebrates than those of the channelized reach. Restoration provided a relatively stable edge habitat, contributing to the recovery of macroinvertebrate communities in such channelized lowland rivers. The placement of groynes can be an effective method of in-stream habitat restoration for macroinvertebrates.

- 151 - Näslund I., 1989. Effects of habitat improvement on the brown trout, Salmo trutta L., population of a northern Swedish stream. Aquaculture and fisheries management, 20 : 463-474.

Abstract : Effects of four types of habitat improvement structures have been evaluated in Laktabäcken Creek, a steep and infertile brown trout, *Salmo trutta* L., stream in Northern Sweden. Boulder dams proved to be the most efficient structure, increasing brown trout densities by up to three times and standing crop by up to five times their original values. Log deflectors gave similar effects on standing crop while boulder groupings and boulder deflectors seemed to be inefficient. Older/larger fish were primarily favoured. No increase in growth or enhanced condition has been registered. Obviously, profitable stream positions for older fish were lacking in Laktabäcken Creek. An increase in the amount of cover and an increase in the winter survival might be secondary effects of alterations.

- 152 - Negishi J.N., & Richardson J.S., 2003. Responses of organic matter and macroinvertebrates to placements of boulder clusters in a small stream of southwestern British Columbia, Canada. Canadian Journal of Fisheries and Aquatic Sciences, 60(3): 247–258.

Abstract: Diversity and productivity of stream food webs are related to habitat heterogeneity and efficiency of energy retention. We tested the hypothesis that experimental boulder placements in a second-order stream would increase diversity and abundance of macroinvertebrates by restoring detrital retention and habitat heterogeneity. Two relatively natural, upstream, reference reaches and a downstream treatment reach with a relatively straight channel and less woody debris were studied for

3 months before and 1.2 years after the placement of six boulder clusters in the treatment reach. Mean velocity and its coefficient of variation increased in the treatment reach (140 and 115%, respectively), whereas the reference reaches remained relatively unchanged after the placements. Enhanced particulate organic matter storage (550%) was accompanied by increased total macroinvertebrate abundance (280%) in the treatment reach, converging with those of the reference reaches almost 1 year after the treatment. Detritivorous taxa numerically dominated the macroinvertebrate community, the total densities of which were best predicted by the fine fraction of organic matter biomass at microhabitat scale. However, the effect of boulder clusters on taxonomic richness was negligible. Our findings suggest that boulder clusters can be used at least as a short-term means to restore macroinvertebrate productivity in detritus-based stream systems.

Résumé : Il existe une relation entre la diversité et la productivité des réseaux alimentaires en eau courante, d'une part, et l'hétérogénéité de l'habitat et l'efficacité de la rétention de l'énergie, d'autre part. Nous avons éprouvé l'hypothèse selon laquelle l'addition expérimentale de blocs de pierre dans un cours d'eau d'ordre 2 devrait augmenter la diversité et l'abondance des macroinvertébrés, en rétablissant la rétention du détritus et l'hétérogénéité de l'habitat. Nous avons étudié deux sections témoins en amont relativement naturelles et une section expérimentale en aval à chenal relativement droit et avec moins de débris ligneux durant les 3 mois qui ont précédé et durant 1,2 année qui a suivi l'addition de six amas de blocs de pierre dans la section expérimentale. La vitesse moyenne et son coefficient de variation ont augmenté dans la section expérimentale (respectivement de 140 % et de 115 %), alors que les conditions dans les sections témoins sont demeurées à peu près inchangées. L'accumulation accrue de matière organique particulaire (550 %) s'est accompagnée dans la section expérimentale d'une augmentation de l'abondance totale des macroinvertébrés (280 %) qui tendait à atteindre l'abondance observée dans les sections témoins presque 1 an après l'addition des blocs. En nombre, ce sont les taxons de détritivores qui dominaient dans la communauté de macroinvertébrés et leurs densités totales pouvaient être prédites le plus exactement par la fraction fine de la biomasse de la matière organique à l'échelle du microhabitat. Il n'y a eu qu'un effet négligeable des blocs de pierre sur la richesse taxonomique. Nos résultats laissent croire que des amas de blocs de pierre peuvent servir, au moins à court terme, à restaurer la productivité des macroinvertébrés dans les systèmes d'eau courante à base de détritus.

- 153 - Nickelson T.E., Solazzi M.F., Johnson S.L. & Rodgers J.D., 1992. Effectiveness of selected stream improvement techniques to create suitable summer and winter rearing habitat for juvenile coho salmon (Oncorhynchus kisutch) in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences, 49(4) : 790-794.

Abstract : We examined the use of constructed pools by juvenile coho salmon (*Oncorhynchus kisutch*) during summer and winter. Log, gabion, and rock structures placed across the full stream width provided good summer habitat but poor winter habitat for juvenile coho salmon. Rearing densities in constructed habitats during summer and winter were generally similar to those in natural habitats of the same type, except that constructed dammed pools supported lower densities during winter than natural dammed pools. The addition of brush bundles to pools created by full-stream-width structures increased the density to juvenile coho salmon in dammed pools during winter, but not in plunge pools. We concluded that the development of off-channel habitat has the greatest potential to increase production of wild coho salmon smolts in Oregon coastal streams.

- 154 - Niezgoda S.L. & Johnson P.A., 2005. Improving the Urban Stream Restoration Effort: Identifying Critical Form and Processes Relationships. Environmental Management, 35(5) : 579-592.

Keywords : stream restoration • natural channel design • urbanization • channel morphology • channel processes • stream classification.

Abstract : Stream restoration projects are often based on morphological form or stream type and, as a result, there needs to be a clear tie established between form and function of the stream. An examination of the literature identifies numerous relationships in naturally forming streams that link morphologic form and stream processes. Urban stream restoration designs often work around infrastructure and incorporate bank stabilization and grade control structures. Because of these

imposed constraints and highly altered hydrologic and sediment discharge regimens, the design of urban channel projects is rather unclear. In this paper, we examine the state of the art in relationships between form and processes, the strengths and weaknesses of these existing relationships, and the current lack of understanding in applying these relationships in the urban environment. In particular, we identify relationships that are critical to urban stream restoration projects and provide recommendations for future research into how this information can be used to improve urban stream restoration design. It is also suggested that improving the success of urban restoration projects requires further investigation into incorporating process-based methodologies, which can potentially reduce ambiguity in the design and the necessity of using an abundant amount of in-stream structures.

- 155 - Niezgoda S.L. & Johnson P.A, 2006. Modeling the long-term impacts of using rigid structures in stream channel restoration. Journal of the American Water Resources Association, 42(6) : 1597–1613.

Abstract: Natural channel designs often incorporate rigid instream structures to protect channel banks, provide grade control, promote flow deflection, or otherwise improve channel stability. The long term impact of rigid structures on natural stream processes is relatively unknown. The objective of this study was to use long term alluvial channel modeling to evaluate the effect of rigid structures on channel processes and assess current and future stream channel stability. The study was conducted on Oliver Run, a small stream in Pennsylvania relocated due to highway construction. Field data were collected for one year along the 107 m reach to characterize the stream and provide model input, calibration, and verification data. FLUVIAL-12 was used to evaluate the long term impacts of rigid structures on natural channel adjustment, overall channel stability, and changing form and processes. Based on a consideration of model limitations and results, it was concluded that the presence of rigid structures reduced channel width-to-depth ratios, minimized bed elevation changes due to long term aggradation and degradation, limited lateral channel migration, and increased the mean bed material particle size throughout the reach. Results also showed how alluvial channel modeling can be used to improve the stream restoration design effort.

- 156 - Nienhuis P.H., Bakker J.P., Grootjans A.P., Gulati R.D. & De Jonge V.N., 2002. The state of the art of aquatic and semi-aquatic ecological restoration projects in the Netherlands. Hydrobiologia, 478(1-3) : 219-233.

Abstract : The Netherlands are a small, low-lying delta in W. Europe (42000 km^2; 50°–54° N; 3°–8° E), mainly consisting of alluvial deposits from the North Sea and from the large rivers Rhine and Meuse. The country was `created by man'. The conversion of natural aquatic and terrestrial ecosystems into drained agricultural land was a major cultural operation over the past 1000 years. Roughly 55% of the country's surface area is still agricultural land. Some decades ago, The Netherlands' landscape was characterised by an armoured coastline and bridled estuaries, a drastically reduced area of saline and freshwater marshes, fully regulated rivers and streams, and numerous artificial lakes. The aquatic ecosystems beyond the influence of the large rivers, the Pleistocene raised bogs and moor lands, have almost been completely annihilated in the past. Acidification and eutrophication led to the deterioration of the remaining softwater lake vegetation. Last but not least, an artificial drainage system was constructed, leading to an unnatural water table all over the country, high in summer, low in winter. Only very recently, some 25 years ago, the tide has been turned and ecological rehabilitation and restoration of disturbed ecosystems are in full swing now, enhanced by the European Union policy to set aside agricultural land in the Netherlands in favour of the development of `nature'. The state of the art of aquatic and semi-aquatic ecological restoration projects in the Netherlands is given. Starting from the conceptual basis of restoration ecology, the successes and failures of hundreds of restoration projects are given. Numerous successful projects are mentioned. In general, ecological restoration endeavours are greatly benefiting from progressive experience in the course of the years. Failures mainly occur by insufficient application of physical, chemical or ecological principles. The spontaneous colonisation by plants and animals, following habitat reconstruction, is preferred. But sometimes the re-introduction of keystone species (e.g. eelgrass; salmon; beaver) is necessary in case the potential habitats are isolated or fragmented, or when a seed bank is lacking, thus not allowing viable populations to develop. Re-introduction of traditional management techniques (e.g. mowing without fertilisation; low intensity grazing) is important to rehabilitate the semi-natural and cultural landscapes, so characteristic for the

Netherlands. For aquatic ecosystems proper (estuaries, rivers, streams, larger lakes) the rule of thumb is that re-establishment of the abiotic habitat conditions is a pre-requisite for the return of the target species. This implies rehabilitation of former hydrological end geomorphological conditions, and an increase in spatial heterogeneity. The `bottom-up' technique of lake restoration, viz. reduction in nutrient loadings, and removal of nutrient-rich organic sediment, is the preferred strategy. The `top-down' approach of curing eutrophicated ecosystems, that is drastic reduction of fish stock, mainly bream, and introduction of carnivorous fish, may be considered as complementary. For semi-aquatic ecosystems (river-fed and rain-fed peat moors, brook valleys, coastal dune slacks) it also counts that the abiotic constraints should be lifted, but here the species-oriented conservation strategy, the enhancement of the recovery of characteristic plant and animal species, is mainly followed. An important pre-requisite for the rehabilitation of the original natural or semi-natural.

- 157 - O'Donnell T.K. & Galat D.L., 2007. River Enhancement in the Upper Mississippi River Basin: Approaches Based on River Uses, Alterations, and Management Agencies. Restoration Ecology, 15(3) : 538–549.

Abstract : The Upper Mississippi River is characterized by a series of locks and dams, shallow impoundments, and thousands of river channelization structures that facilitate commercial navigation between Minneapolis, Minnesota, and Cairo, Illinois. Agriculture and urban development over the past 200 years have degraded water quality and increased the rate of sediment and nutrient delivery to surface waters. River enhancement has become an important management tool employed to address causes and effects of surface water degradation and river modification in the Upper Mississippi River Basin. We report information on individual river enhancement projects and contrast project densities, goals, activities, monitoring, and cost between commercially non-navigated and navigated rivers (Non-navigated and Navigated Rivers, respectively). The total number of river enhancement projects collected during this effort was 62,108. Cost of all projects reporting spending between 1972 and 2006 was about US$1.6 billion. Water quality management was the most cited project goal within the basin. Other important goals in Navigated Rivers included in-stream habitat improvement and flow modification. Most projects collected for Non-navigated Rivers and their watersheds originated from the U.S. Department of Agriculture (USDA). The U.S. Army Corps of Engineers and the USDA were important sources for projects in Navigated Rivers. Collaborative efforts between agencies that implement projects in Non-navigated and Navigated Rivers may be needed to more effectively address river impairment. However, the current state of data sources tracking river enhancement projects deters efficient and broad-scale integration.

- 158 - O'Donnell TK, Galat DL., 2008. Evaluating success criteria and project monitoring in river enhancement within an adaptive management framework. Environmental Management, 41(1):90-105.

Abstract : Objective setting, performance measures, and accountability are important components of an adaptive-management approach to river-enhancement programs. Few lessons learned by river-enhancement practitioners in the United States have been documented and disseminated relative to the number of projects implemented. We conducted scripted telephone surveys with river-enhancement project managers and practitioners within the Upper Mississippi River Basin (UMRB) to determine the extent of setting project success criteria, monitoring, evaluation of monitoring data, and data dissemination. Investigation of these elements enabled a determination of those that inhibited adaptive management. Seventy river enhancement projects were surveyed. Only 34% of projects surveyed incorporated a quantified measure of project success. Managers most often relied on geophysical attributes of rivers when setting project success criteria, followed by biological communities. Ninety-one percent of projects that performed monitoring included biologic variables, but the lack of data collection before and after project completion and lack of field-based reference or control sites will make future assessments of ecologic success difficult. Twenty percent of projects that performed monitoring evaluated >/=1 variable but did not disseminate their evaluations outside their organization. Results suggest greater incentives may be required to advance the science of river enhancement. Future river-enhancement programs within the UMRB and elsewhere can increase knowledge gained from individual projects by offering better guidance on setting success criteria before project initiation and evaluation through established monitoring protocols.

- 159 - Paller M.H., Reichter M.J.M., Dean J.M. & Seigle J.C., 2000. Use of fish community data to evaluate restoration success of a riparian stream. Ecological Engineering, 15(1) : S171-S187.

Keywords : restoration • streams • fish • indicators • reforestation.

Abstract : From 1985 to 1988, stream and riparian habitats in Pen branch and Four Mile branch began recovering from deforestation caused by the previous release of hot water from nuclear reactors. The Pen branch corridor was replanted with wetland trees in 1995 to expedite recovery and restore the Pen branch ecosystem. Pen branch, Four Mile branch, and two relatively undisturbed streams were electrofished in 1995/1996 to determine how fish assemblages differed between the previously disturbed and undisturbed streams and whether such difference could be used to measure restoration success in Pen branch. Fish assemblages were analyzed using nonparametric multivariate statistical methods and the index of biotic integrity (IBI), a bioassessment method based on measurement of ecologically sensitive characteristics of fish assemblages. Many aspects of fish assemblage structure (e.g. species richness, disease incidence, taxonomic composition at the family level) did not differ between disturbed and undisturbed streams; however, the disturbed streams were characterized by higher densities of a number of species. These differences were successfully detected with the multivariate statistical methods; whereas, the IBI did not differ between most recovering and undisturbed sampling sites. Because fish assemblages are strongly influenced by instream habitat, and because instream habitat is strongly influenced by the riparian zone, fish assemblages can be used to measure restoration success. Nonparametric ordination methods may provide the most sensitive measure of progress towards restoration goals, although the IBI can be used during early stages of recovery to indicate when certain ecologically important aspects of structure and function in recovering streams have reached levels typical of undisturbed streams.

- 160 - Palm D., Brännäs E., Lepori F., Nilsson K. & Stridsman S., 2007. The influence of spawning habitat restoration on juvenile brown trout (*Salmo trutta*) density. Canadian Journal of Fisheries and Aquatic Sciences, 64(3) : 509-515.

Abstract : Between 1992 and 2003, we assessed the density of age-0+ brown trout (*Salmo trutta*) in a channelized stream in northern Sweden, which was restored using two different schemes. One section of the stream was restored by the addition of boulders and reconstruction of gravel beds (boulder + gravel section), whereas another section was restored through addition of boulders only (boulder-only section). In addition, we compared the substrate size composition of gravel beds and the egg-to-fry survival between the two stream sections, and we related the density of age-0+ brown trout to the area of reconstructed gravel beds. After the restoration, the density of age-0+ brown trout increased significantly in the boulder + gravel section and was positively correlated with the area of reconstructed gravel beds. By contrast, the density of age-0+ brown trout did not change in the boulder-only treatment. Egg-to-fry survival was significantly higher in the boulder + gravel section compared with the boulder-only section, probably because of the higher content of sand and fines in the gravel beds of the latter treatment. This study shows that the density of age-0+ brown trout was limited by the availability and quality of spawning substrate rather than by the structural habitat complexity.

Résumé : De 1992 à 2003, nous avons évalué la densité des truites brunes (*Salmo trutta*) d'âge 0+ dans un cours d'eau canalisé du nord de la Suède, qui a été restauré selon deux arrangements différents. Une section a été restaurée par l'addition de blocs de pierre et la reconstruction des lits de gravier (section blocs + gravier), alors qu'une autre section n'a reçu que des blocs (section blocs seuls). De plus, nous avons comparé la composition en taille du substrat dans les lits de gravier et la survie de l'oeuf à l'alevin dans les deux sections de cours d'eau; nous avons mis en relation la densité des truites brunes d'âge 0+ à la surface des lits de gravier reconstruits. Après la restauration, la densité des truites brunes d'âge 0+ a augmenté significativement dans la section blocs + gravier où elle est en corrélation positive avec la surface des lits de gravier reconstitués. Au contraire, la densité des truites d'âge 0+ n'a pas changé dans la section ayant reçu les blocs seuls. La survie de l'oeuf à l'alevin est significativement plus importante dans la section blocs + gravier que dans la section blocs seuls, probablement à cause du contenu plus grand de sable et de sédiments fins dans les lits de gravier de cette dernière section. Notre étude montre que la densité des truites d'âge 0+ est limitée

par la disponibilité et la qualité des substrats de fraie plutôt que par la complexité structurale de l'habitat.

- 161 - Palmer M.A., Bernhardt E.S., Allan J.D., Lake P.S., Alexander G., Brooks S., Carr J., Clayton S., Dahm N., Follstad-Shah J., Galat D.L., Loss S.G., Goodwin P., Hart D.D., Hassett B., Jenkinson R., Kondolf G.M., Lave R., Meyer J.L., O'Donnell T.K., Pagano L. & Sudduth E., 2005. Standards for ecologically successful river restoration. Journal of Applied Ecology, 42(2) : 208–217.

Key-words: ecosystem rehabilitation • floodplain • monitoring • restoration assessment • stream.

Abstract :

1- Increasingly, river managers are turning from hard engineering solutions to ecologically based restoration activities in order to improve degraded waterways. River restoration projects aim to maintain or increase ecosystem goods and services while protecting downstream and coastal ecosystems. There is growing interest in applying river restoration techniques to solve environmental problems, yet little agreement exists on what constitutes a successful river restoration effort.

2- We propose five criteria for measuring success, with emphasis on an ecological perspective. First, the design of an ecological river restoration project should be based on a specified guiding image of a more dynamic, healthy river that could exist at the site. Secondly, the river's ecological condition must be measurably improved. Thirdly, the river system must be more self-sustaining and resilient to external perturbations so that only minimal follow-up maintenance is needed. Fourthly, during the construction phase, no lasting harm should be inflicted on the ecosystem. Fifthly, both pre- and post-assessment must be completed and data made publicly available.

3- Determining if these five criteria have been met for a particular project requires development of an assessment protocol. We suggest standards of evaluation for each of the five criteria and provide examples of suitable indicators.

4- *Synthesis and applications*. Billions of dollars are currently spent restoring streams and rivers, yet to date there are no agreed upon standards for what constitutes ecologically beneficial stream and river restoration. We propose five criteria that must be met for a river restoration project to be considered ecologically successful. It is critical that the broad restoration community, including funding agencies, practitioners and citizen restoration groups, adopt criteria for defining and assessing ecological success in restoration. Standards are needed because progress in the science and practice of river restoration has been hampered by the lack of agreed upon criteria for judging ecological success. Without well-accepted criteria that are ultimately supported by funding and implementing agencies, there is little incentive for practitioners to assess and report restoration outcomes. Improving methods and weighing the ecological benefits of various restoration approaches require organized national-level reporting systems.

- 162 - Palmer M., Allan J.D., Meyer J. & Bernhardt E.S, 2007. River Restoration in the Twenty-First Century: Data and Experiential Knowledge to Inform Future Efforts. Restoration Ecology, 15(3) : 472–481.

Abstract : Despite some highly visible projects that have resulted in environmental benefits, recent efforts to quantify the number and distribution of river restoration projects revealed a paucity of written records documenting restoration outcomes. Improving restoration designs and setting watershed priorities rely on collecting and making accessible this critical information. Information within the unpublished notes of restoration project managers is useful but rarely documents ecological improvements. This special section of *Restoration Ecology* is devoted to the current state of knowledge on river restoration. We provide an overview of the section's articles, reflecting on lessons learned, which have implications for the implementation, legal, and financing frameworks for restoration. Our reflections are informed by two databases developed under the auspices of the National River Restoration Science Synthesis project and by extensive interactions with those who fund, implement, and permit restoration. Requiring measurable ecological success criteria, comprehensive watershed plans, and tracking of when and where restoration projects are implemented are critical to improving the health of U.S. waters. Documenting that a project was put in the ground and stayed intact cannot be equated with ecological improvements. However, because

significant ecological improvements can come with well-designed and -implemented stream and river restorations, a small investment in documenting the factors contributing to success will lead to very large returns in the health of our nation's waterways. Even projects that may appear to be failures initially can be turned into success stories by applying the knowledge gained from monitoring the project in an adaptive restoration approach.

- 163 - Parasiewicz P., 2001. MesoHABSIM: A concept for application of instream flow models in river restoration planning. Fisheries, 26(9) : 6-13.

Abstract : This paper describes the methodological concept for application of physical habitat models to restoration planning at a whole river scale. The design proposed here builds upon the Instream Flow Incremental Methodology but is focused at the need for managing large-scale habitats and river systems. It modifies the data acquisition technique and analytical resolution of standard approaches, changing the scale of physical parameters and biological response assessment from micro- to meso-scale. In terms of technological process, a highly detailed microhabitat survey of a few, short sampling sites would be replaced by mesohabitat mapping of whole-river sections. As with more traditional stream habitat models, the variation in the spatial distribution and amount of mesohabitats can provide key information on habitat quality changes corresponding to alterations in flow, channel changes, and stream improvement measures. However, the scale of simulations more closely matches restoration and system analyses, because it provides a solid base for quantitative assessment and simulation of habitat conditions for the whole stream.

- 164 - Pedersen M.L., Friberg N., Skriver J., Baattrup-Pedersen J. & Larsen S.E., 2007a. Restoration of Skjern River and its valley: Project description and general ecological changes in the project area. Ecological engineering, 30(2) : 131-144.

Keywords: restoration • river • river valley • wetland • nutrients • deposition • rare species • fish • vegetation • macroinvertebrates.

Abstract : During the period 1999–2002, 19 km of the Skjern River and 22 km^2 of the cultivated river valley were restored into a meandering river, wetlands, meadows and shallow lakes. The restoration followed a channelisation of the river and an artificial draining and reclamation of the river valley for agriculture in the 1960s. In 1987, the Danish Parliament decided to carry out the restoration to reduce the nutrient loading to the sea and enhance the re-creational value of the river valley. A comprehensive monitoring programme was initiated to follow the short-term ecological consequences of the restoration.
The river valley changed from agricultural fields into meadows with a rapid succession in plant species. The retention of nutrients in the restored area follows the extent of flooding and amounted to less than 10% of the total riverine transport. The new river was rapidly colonised with plants and invertebrates from upstream reaches, and rare species in the project area generally seem to thrive under the new conditions. The new shallow lakes and the meadows caused a minor increase in the predation of salmon and trout smolts because of the increased populations of fish-eating birds.

- 165 - Pedersen M.L., Friberg N., Skriver J., Baattrup-Pedersen J. & Larsen S.E., 2007b. Restoration of Skjern River and its valley—Short-term effects on river habitats, macrophytes and macroinvertebrates. Ecological Engineering 30(2) : 145-156.

Keywords : river restoration • short-term effects • colonization • monitoring • macroinvertebrate diversity • macrophyte coverage.

Abstract : The lower 19 km of the Skjern River was restored and transformed into a 26 km long meandering river. Three survey reaches and one control reach upstream of the restoration area were surveyed to assess the short-term effects of the restoration on river habitats, macrophytes and macroinvertebrates. The reaches were surveyed before the restoration in 2000 and again after the restoration in 2003. Morphological adjustments were evident in the re-meandered river and the habitat structure (depth, current velocity and substratum) became more diverse. The macrophyte coverage was 34% before the restoration. Restoration included removal of dense near bank vegetation stands

of *Glyceria maxima*, and in 2003 re-colonization of the restored reaches had resulted in 24% macrophyte coverage. Species composition and growth patterns changed significantly in the edge habitat and the dominant macrophyte *G. maxima* was replaced by *Elodea canadensis* and *Sparganium* sp. Macroinvertebrates rapidly colonized the restored reaches and increased the community diversity. Only one taxon, Heptageniidae, significantly increased in abundance after the restoration and a more even distribution of taxa developed on the restored reaches. Biological communities will continue to develop over the coming years as the river becomes more physically stable. Hence the macroinvertebrate and macrophyte communities will adjust and colonization from upstream sources and other systems will probably increase biodiversity.

- 166 - Platts W.S. & Rinne J.N., 1985. Riparian and Stream Enhancement Management and Research in the Rocky Mountains. North American Journal of Fisheries Management, 5(2a) : 115-125.

Abstract : This report reviews past stream enhancement research in the Rocky Mountains, its adequacy, and research that should be done to improve the effectiveness of future stream enhancement projects. Research is lacking on stream improvement in a watershed context on a long-term basis. Not all streams can be enhanced. Enhancement should be attempted only after techniques described in the literature have been carefully considered and judged appropriate for the selected site.

- 167 - Poole G.C., Frissell C.A., Ralph S.C., 1997. In-stream habitat unit classification : inadequacies for monitoring and some consequences for management. Journal of the American Water Resources Association, 33 (4), 879–896.

Abstract : Habitat unit classification can be a useful descriptive tool in hierarchical stream classification. However, a critical evaluation reveals that it is applied inappropriately when used to quantify aquatic habitat or channel morphology in an attempt to monitor the response of individual streams to human activities. First, due to the subjectivity of the measure, observer bias seriously compromises repeatability, precision, and transferability of the method. Second, important geomorphic and ecological changes in stream habitats are not always manifested as changes in habitat-unit frequency or characteristics. Third, classification data are nominal, which can intrinsically limit their amenability to statistical analysis. Finally, using the frequency of specific habitat unit types (e.g., pool/riffle ratio or percent pool) as a response variable for stream monitoring commonly leads to the establishment of management thresholds or targets for habitat-unit types. This, in turn, encourages managers to focus on direct manipulation or replacement of habitat structures while neglecting long-term maintenance or re-establishment of habitat-forming biophysical processes. Stream habitat managers and scientists should only use habitat unit classification to descriptively stratify in-stream conditions. They should not use habitat unit classification as a means of quantifying and monitoring aquatic habitat and channel morphology. Monitoring must instead focus on direct, repeatable, cost-efficient, and quantitative measures of selected physical, chemical, and biological components and processes spanning several scales of resolution.

- 168 - Pretty J.L., Harrison S.S., Shepherd D.J., Smith C., Hildrew A.G. & Hey R.D., 2003. River rehabilitation and fish populations: assessing the benefit of instream structures. Journal of Applied Ecology, 40(2) : 251-265.

Key-words: artificial riffles • flow deflectors • habitat heterogeneity • rehabilitation potential.

Abstract:

1. River rehabilitation schemes are now widespread in the UK and elsewhere, but there have been few systematic assessments of their ecological effect, particularly on target organisms such as fish. Fish populations were therefore assessed in 13 lowland rivers using point abundance measures and depletion electrofishing. Each river was sampled in two reaches, respectively containing a small-scale rehabilitation scheme (artificial riffles or flow deflectors) and an unrehabilitated control reach. Detailed geomorphological surveys were undertaken for the two study reaches in each river to assess the physical and hydraulic effect of rehabilitation.

2. There were large qualitative and quantitative differences among rivers and some had relatively impoverished fish faunas. Overall, total fish abundance, species richness, diversity and equitability were not significantly different between rehabilitated and control reaches. This was true for both the sampling methods used. Bullhead *Cottus gobio* and stone loach *Barbatula barbatula* tended to be more abundant in rehabilitated reaches, but this was significant only for artificial riffles. There was a significant between-year difference in fish abundance.
3. In general, rehabilitation schemes increased depth and flow heterogeneity, and fish species richness and diversity appeared to respond positively to increased flow velocity in restored reaches. However, there were few significant relationships between the fish fauna and physical variables, indicating that increasing physical (habitat) heterogeneity does not necessarily lead to higher biological diversity. We therefore caution against the use of physical responses to rehabilitation as a surrogate or reliable predictor of ecological response.
4. The weak response of fishes to rehabilitation may have been because the schemes were inappropriate in design and scale for low-gradient rivers. Furthermore, fish assemblages may have lacked the potential for recovery because of poor water quality and/or because the schemes were isolated within longer sections of degraded river. More extensive and directed biological monitoring is essential to improve understanding and enable future improvements in the design of schemes and the selection of sites with greater potential for successful rehabilitation.
5. *Synthesis and applications.* From this substantial sample of lowland rivers, there is little evidence of any general benefit to fish of small-scale instream structures in river rehabilitation. From present ecological knowledge it may be that resources would be better devoted to promoting the development of lateral and off-channel habitats within the river corridor. Physical restoration will be most effective when used alongside other strategies to augment fish populations such as water quality

- 169 - Price D.J. & Birge W.L., 2005. Effectiveness of stream restoration following highway reconstruction projects on two freshwater streams in Kentucky. Ecological Engineering, 25(1) : 73-84.

Keywords : stream remediation • habitat assessment • rapid bioassessment protocols • fish index of biotic integrity.

Abstract : After new highway construction near or across a stream, the site often requires remediation to reestablish suitable habitat for local biota. This study addresses effectiveness of environmental mitigation efforts for these construction projects, and contributes to the development of a protocol for environmental mitigation to be adopted by the Kentucky Transportation Cabinet. Effects of remediation on two small KY, USA, streams, Cedar Creek and Holts Creek, were assessed using U.S. EPA Rapid Bioassessment Protocols (RBP). Habitat assessments and fish species assemblage surveys (index of biotic integrity) were conducted for three sectors of each stream. A decrease in total habitat assessment scores was observed at the remediated sector in each stream. However, for both streams the IBI fish assemblage scores were similar for upstream and remediated sectors, indicating that habitat impact resulted in limited effects on fish assemblages. The overall score for the downstream reach of Cedar Creek also was similar to upstream and remediated sectors, but the downstream portion of Holts Creek scored lower, primarily because of reduced number of fish species and abundances. This was likely due to stream characteristics and lack of diversity. The U.S. EPA Rapid Bioassessment Protocols proved to be well suited for quantitative assessments of fish assemblages for small stream sectors with limited impacted areas. Although habitat quality scored somewhat lower in the remediated sectors of both streams, there were no major impairments of overall stream productivity and no apparent blockage of fish migration. The most apparent deficiencies in habitat restoration involved protective and riparian vegetation, resulting in diminished bank stability, increased prospects for bank erosion, moderate downstream siltation, and consequences of stream channelization.

- 170 - Purcel A.H., Friedrich C. & Resh V.h., 2002. An Assessment of a Small Urban Stream Restoration Project in Northern California. Restoration Ecology, 10(4) : 685-694.

Abstract : Stream restoration projects have become increasingly common, and the need for systematic post-project evaluation, particularly for small-scale projects, is evident. This study describes how a 70-m restored reach of a small urban stream, Baxter Creek (in Poinsett Park, El Cerrito, California), was quickly and inexpensively evaluated using habitat, biological, and resident-attitude assessments. The restoration involved opening a previously culverted channel, planting riparian vegetation, and adding in-stream step-pool sequences and sinuosity. Replicated benthic macroinvertebrate samples from the restored site and an upstream unrestored site were compared using several metrics, including taxa richness and a biotic index. Both biological and habitat quality improved in the restored compared with the unrestored section. However, when compared with a creek restored 12 years before, habitat condition was of lower quality in the recently restored creek. A survey of the neighborhood residents indicated that, overall, they were pleased with the restored creek site. The approach used in this demonstration project may be applicable to other small-scale evaluations of urban stream restorations.

- 171 - Quinn J.W. & Kwak T.J., 2000. Use of Rehabilitated Habitat by Brown Trout and Rainbow Trout in an Ozark Tailwater River. North American Journal of Fisheries Management, 20(3) : 737–751.

Abstract : We evaluated instream and riparian habitat rehabilitation that was completed following catastrophic flooding in the White River, below Beaver Dam, Arkansas. Most rehabilitation structures were designed to stabilize the river banks and increase cover for trout (Salmonidae) during high flows associated with hydroelectric power generation. We quantified trout response to rehabilitation at two spatial scales—microhabitat and river reach. At the microhabitat scale, brown trout *Salmo trutta* and rainbow trout *Oncorhynchus mykiss* occupied the deepest habitats available and were randomly associated with cover at low flow (about 1 m^3/s). Principal-component scores describing physical characteristics of brown trout and rainbow trout microhabitats were significantly different from available-habitat scores at high flow (about 215 m^3/s), when trout were strongly associated with velocity refugia near the river margins—habitats similar to those created by rehabilitation structures. At the reach scale, trout population size and structure were estimated in modified (700-m) and reference (800-m) reaches before and after rehabilitation. Total trout density and biomass in the modified reach increased after rehabilitation relative to that of the reference reach, evidence that the modified reach supported more fish after rehabilitation. Analyses stratified by salmonid species and size indicated that the observed effect was primarily due to rainbow trout and small trout (10.0–19.9 cm) of all species shifting their distributions into the modified reach. Our results suggest that instream and riparian habitat rehabilitation structures commonly applied to small streams are a valid management technique for large tailwater rivers. However, implementation in each system should be carefully evaluated, and management expectations for large trout should be conservative. Because of the observed benefit for small trout, placement of rehabilitation structures near spawning areas should be considered when management for wild trout is a priority. Finally, we suggest integration of instream and riparian habitat rehabilitation into broader management plans when applied to regulated rivers.

- 172 - Raborn S.W. & Schramm H.L.Jr., 2003. Fish assemblage response to recent mitigation of a channelized warmwater stream. River Research and Applications, 19(4) : 289-301.

Keywords : channelization • mitigation • fish • assemblage • stream • habitat • incision • diversity.

Abstract : Various designs of low-head dams are used to rehabilitate streams or forestall upstream channel incision after channelization. We report on the efficacy of using notched sills and grade control structures (GCS) to restore the fish assemblage in Luxapallila Creek, Mississippi. We tested the null hypotheses that habitat variables and species richness, evenness, and assemblage structure would not differ among: (1) a channelized segment with no modifications; (2) a channelized segment mitigated by the installation of sills and GCS; (3) a segment upstream of the installations and undergoing channel incision; and (4) an unaltered segment. Although habitat variables changed, neither species richness, evenness, nor fish assemblage structure differed between mitigated and channelized segments with both exhibiting less richness and different assemblage structures than the

unaltered segment. Lack of differences in species richness between the incised and unaltered segments suggest that the GCS may have halted the negative effects of upstream channel incision before species were extirpated. Conspicuous habitat differences between the altered (channelized and mitigated) and unaltered segments were lack of backwaters and canopy coverage and finer substrates in the altered segments. Our results suggest a more comprehensive rehabilitation strategy is required in Luxapallila Creek.

- 173 - Reich M., Kershner J.L. & Wildman R.C., 2003. Restoring stream with large wood : a synthesis. American Fisheries Society Symposium. 11p.

Abstract : The use of large wood in stream restoration projects has become increasingly popular in the last 20 years. We reviewed more than 30 case studies from different ecoregions and countries (Canada, Germany, Japan, United States) to evaluate the variety of approaches used and assessed their reported success. Wood inputs generally fell into two categories: fixed structural designs or placements where wood was not fixed to one location. Large wood was used in fixed designs in most studies from North America and usually built in or anchored by cables. Few projects attempted to simulate the dynamic processes of wood inputs to the floodplain. Mobile wood placements were mostly used in projects after 1990. They represented 6% of the projects in North America and 55% in Germany, where restoration projects designed with mobile wood can be found even in densely populated (200 people/km²) rural areas, but only along second- and third-order streams. Few studies attempted to simulate historical amounts and distribution of wood in forested catchments. In most of the studies from rural areas, practical aspects like stream access or the availability of logs dominated the experimental design and placements.

- 174 - Richards C., Cernera P.J., Ramey M.P. & Reiser D.W., 1992. Development of Off-Channel Habitats for Use by Juvenile Chinook Salmon. North American Journal of Fisheries Management, 12(4) : 721-727.

Abstract : Fisheries habitat improvement frequently requires the exploitation of existing or artificial features of stream channels and associated floodplains. Along the Yankee Fork of the Salmon River, four series of off channel mining dredge ponds were connected to the river by excavating channels; surface-water control structures were installed to regulate flow through each series of ponds. The project was created to increase rearing habitat for juvenile chinook salmon *Oncorhynchus tshawytscha*. Highest fish densities (5.2/m^2) in the newly constructed pond series were in connecting channel habitats. These densities were higher than those reported in other streams and may have been related to the hatchery origin of the stocked fish. Densities observed in the ponds were similar to those reported in natural habitats. Addition of habitats through incorporation of dredge ponds increases management options for rebuilding chinook salmon populations in the stream.

- 175 - Riley S.C. & Fausch K.D., 1995. Trout population response to habitat enhancement in six northern Colorado streams. Canadian journal of fisheries and aquatic sciences, 52(1) : 34-53.

Abstract : Nous avons examiné les effets de l'installation de déversoirs en bois sur les populations de truites de six petites ruisseaux peu accessibles des Montagnes Rocheuses. La pression de pêche sportive était faible sur tous ces cours d'eau, et la plupart des pêcheurs ne tuaient aucun poisson. Les structures ont été installées dans des tronçons aménagés de 250 m à l'été 1988, et les résultats ont été comparés à ceux de tronçons témoins adjacents, de 250 m, entre 1987 et 1990. Les déversoirs ont causé des modifications marquées de l'habitat, notamment une forte augmentation du volume des fosses, une baisse de la vitesse du courant, ainsi qu'un accroissement de la profondeur et de la couverture. Après l'installation des structures, l'abondance et la biomasse des truites de deux ans et plus (et souvent d'un an) a augmenté dans les six cours d'eau, mais rien n'indiquait que les truites étaient en meilleure santé ou atteignaient des tailles plus élevées dans la plupart des ruisseaux. La recapture dans deux ruisseaux de truites marquées a révélé que l'installation des déversoirs ne causait pas d'augmentation de la croissance ni de la survie des truites résidantes, mais la recapture dans les autres cours d'eau de truites aux nageoires coupées semble indiquer que le taux apparent de survie peut avoir augmenté temporairement dans les tronçons aménagés. Le faible taux de recapture

de truites marquées et le fort pourcentage d'adultes non marqués indiquent que le taux d'immigration était fort, ce qui permet de penser que le déplacement constitue un mécanisme important qui explique l'accroissement des populations de truite après l'aménagement de l'habitat dans ces cours d'eau.

- 176 - Rohde S., Kienast F. & Bürgi M., 2004. Assessing the Restoration Success of River Widenings: A Landscape Approach. Environmental Management, 34(4) : 574-589.

Keywords ; stencil technique • indicators • assessment • landscape metrics • GIS • random window sampling • riparian habitat • river restoration • Switzerland.

Abstract : During the last 200 years, many rivers in industrialized countries have been modified by canalization. In the last two decades, the philosophy of river management has changed considerably, and restoration of ecological integrity has become an important management goal. One appealing restoration approach is to create “river widenings” that permit braiding within a limited area. This study presents a new and efficient framework for rapidly assessing such widening projects and offers a novel method to comparing restored sites with near-natural stretches (stencil technique). The proposed framework evaluates spatial patterns of riparian habitat types using landscape metrics as indicators. Three case studies from river restoration (river widening) in Switzerland are presented for demonstration purposes.
The method compares restored sites with prerestoration conditions and near-natural conditions, which are assumed to represent the worst and best case states of a river system. To take into account the limited spatial extent of the restored sites, the so-called “stencil technique” was developed, where the landscape metrics of the near-natural reference sites are calculated for both the entire study area and smaller sections (clips). The clips are created by using a stencil that has the exact shape and size of the restored area (random window-sampling technique). Subsequently, the calculated metrics for the restored sites are compared to the range of values calculated for the near-natural data subset.
Our studies show that the proposed method is easy to apply andprovides a valid way to assess the restoration success of river widenings. We found that river widenings offer real opportunities for establishing riparian habitats. However, they promote mainly pioneer successional stages and the habitat mosaic of the restored section is more complex than at the near-natural reference sites.

- 177 - Roni P. & Quinn T.P., 2001a. Density and size of juvenile salmonids in response to placement of large woody debris in western Oregon and Washington streams. Canadian Journal of Fisheries and Aquatic Sciences, 58(2): 282–292.

Abstract: Thirty streams in western Oregon and Washington were sampled to determine the responses of juvenile salmonid populations to artificial large woody debris (LWD) placement. Total pool area, pool number, LWD loading, and LWD forming pools were higher in treatment (LWD placement) than paired reference reaches during summer or winter. Juvenile coho salmon (*Oncorhynchus kisutch*) densities were 1.8 and 3.2 times higher in treated reaches compared with reference reaches during summer and winter, respectively. The response (treatment minus reference) of coho density to LWD placement was correlated with the number of pieces of LWD forming pools during summer and total pool area during winter. Densities of age-1+ cutthroat trout (*Oncorhynchus clarki*) and steelhead trout (*Oncorhynchus mykiss*) did not differ between treatment and reference reaches during summer but were 1.7 times higher in treatment reaches during winter. Age-1+ steelhead density response to treatment during summer was negatively correlated with increases in pool area. Trout fry densities did not differ between reaches, but the response of trout fry to treatment was negatively correlated with pool area during winter. Our research indicates that LWD placement can lead to higher densities of juvenile coho during summer and winter and cutthroat and steelhead during winter.

Résumé : Des échantillonnages dans trente cours d'eau de l'ouest de l'Oregon et du Washington ont permis d'étudier les réactions des populations de jeunes saumons à l'introduction artificielle de débris ligneux de grande taille (LWD) dans le lit du cours d'eau. La surface et le nombre de fosses, la charge de LWD, et l'incidence de fosses formées par la présence de LWD sont toutes plus élevés dans les zones expérimentales dans lesquelles on a ajouté des LWD, que dans les zones témoins appariées, tant en hiver qu'en été. Les densités des jeunes saumons coho (*Onchorhynchus kisutch*) sont 1,8 fois plus grandes que dans les zones témoins durant l'été et 3,2 fois plus élevées en hiver. La modification

de la densité des saumons (densité expérimentale moins densité de la zone témoin) à la suite de l'introduction de LWD est reliée en été au nombre de pièces de LWD qui entraînent la formation de fosses et, en hiver, à la surface totale des fosses. Les densités de la truite fardée (*Oncorhynchus clarki*) et de la truite arc-en-ciel anadrome (*Oncorhynchus mykiss*) d'âge 1+ ne varient pas entre les zones expérimentales et les zones témoins en été, mais sont 1,7 fois plus élevées en hiver dans les zones expérimentales. La densité des truites arc-en-ciel d'âge 1+ en été est en corrélation négative avec l'augmentation de la surface des fosses. Les densités des alevins de la truite fardée ne varient pas d'une section à une autre, mais elles sont en relation négative avec la surface des fosses en hiver. Notre étude montre que l'addition de LWD peut conduire à des densités accrues de saumons coho juvéniles tant en été qu'en hiver, de même que des truites fardées et des truites arc-en-ciel en hiver.

- 178 - Roni P. & Quinn T.P., 2001b. Effects of Wood Placement on Movements of Trout and Juvenile Coho Salmon in Natural and Artificial Stream Channels. Transactions of the American Fisheries Society, 130(4) : 675-685.

Abstract : We monitored the movements of marked juvenile coho salmon *Oncorhynchus kisutch,* steelhead *O. mykiss,* and cutthroat trout *O. clarki* in a stream reach that had been “restored” with placed wood and a reference reach with no wood placement and tracked the growth and movements of individually marked coho salmon among habitats in artificial channels with and without woody debris. Monthly surveys in Shuwah Creek, Washington, indicated that few (0–33%) of the marked trout or coho salmon moved between the restored and reference reaches. However, a rapid decline in both marked and unmarked fish in late fall and the increasing proportion of unmarked fish indicated considerable migration to and from the study reaches. In the artificial channels, fewer fish moved in the simple (with no wood) channel than in the complex (with wood) channel (22% versus 37%), and the mean distance moved was shorter in the complex channel (4.4 versus 6.7 habitat units). In the simple channel, the fish that moved grew faster than those that did not. Movement may facilitate increased growth in stream reaches with little woody debris, and the placement of woody debris may lead to less frequent and shorter movements.

- 179 - Roni P., Beechie T.J., Bilby R.E., Leonetti F.E., Pollock M.M. & Pess G.R., 2002. A Review of Stream Restoration Techniques and a Hierarchical Strategy for Prioritizing Restoration in Pacific Northwest Watersheds. North American Journal of Fisheries Management, 22 : 1-22.

Abstract : Millions of dollars are spent annually on watershed restoration and stream habitat improvement in the U.S. Pacific Northwest in an effort to increase fish populations. It is generally accepted that watershed restoration should focus on restoring natural processes that create and maintain habitat rather than manipulating instream habitats. However, most process-based restoration is site-specific, that is, conducted on a short stream reach. To synthesize site-specific techniques into a process-based watershed restoration strategy, we reviewed the effectiveness of various restoration techniques at improving fish habitat and developed a hierarchical strategy for prioritizing them. The hierarchical strategy we present is based on three elements: (1) principles of watershed processes, (2) protecting existing high-quality habitats, and (3) current knowledge of the effectiveness of specific techniques. Initially, efforts should focus on protecting areas with intact processes and high-quality habitat. Following a watershed assessment, we recommend that restoration focus on reconnecting isolated high-quality fish habitats, such as instream or off-channel habitats made inaccessible by culverts or other artificial obstructions. Once the connectivity of habitats within a basin has been restored, efforts should focus on restoring hydrologic, geologic (sediment delivery and routing), and riparian processes through road decommissioning and maintenance, exclusion of livestock, and restoration of riparian areas. Instream habitat enhancement (e.g., additions of wood, boulders, or nutrients) should be employed after restoring natural processes or where short-term improvements in habitat are needed (e.g., habitat for endangered species). Finally, existing research and monitoring is inadequate for all the techniques we reviewed, and additional, comprehensive physical and biological evaluations of most watershed restoration methods are needed.

- 180 - Roni P., Bennett T. ,Morley S. , Pess G.R. , Hanson K., Van Slyke D. & Olmstead P., 2006. Rehabilitation of bedrock stream channels: the effects of boulder weir placement on aquatic habitat and biota. River Research and Applications, 22 (9) : 967-980. (http://www.nwfsc.noaa.gov/research/divisions/ec/wpg/documents/blm_boulder_weir_final_report_roni_et_al.pdf)

Key-words : restoration • rehabilitation • boulders • weirs • habitat structures • salmonids • macroinvertebrates • coho salmon.

Abstract: The placement of boulder weirs is a popular method to improve fish habitat, though little is known about the effectiveness of these structures at increasing fish and biota abundance. We examined the effectiveness of boulder weir placement by comparing physical habitat, chemical and biotic metrics in 13 paired treatment (boulder weir placement) and control reaches in seven southwest Oregon watersheds in the summer of 2002 and 2003. Pool area, the number of boulders, total large woody debris (LWD) and LWD forming pools were all significantly higher in treatment than control reaches ($p < 0.05$). No differences in water chemistry (total N, total P, dissolved organic carbon) or macroinvertebrate metrics (richness, total abundance, benthic index of biotic integrity etc.) were detected. Abundance of juvenile coho salmon (*Oncorhynchus kisutch*) and trout (*O. mykiss* and *O. clarki*) were higher in treatment than control reaches ($p < 0.05$), while dace (*Rhinichthys* spp.; $p < 0.09$) were more abundant in control reaches and no significant difference was detected for young-of-year trout ($p > 0.20$). Both coho salmon and trout response to boulder weir placement were positively correlated with difference in pool area; $p < 0.10$), while dace and young-of-year trout response to boulder weir placement were negatively correlated with difference in LWD ($p < 0.05$). The placement of boulder weirs appears to be an effective technique for increasing local abundance of species that prefer pools (juvenile coho and trout >100 mm). Based on our results and previous studies on bedrock and incised channels, we suggest that the placement of boulder structures is a useful first step in attempting to restore these types of stream channels.

- 181 - Roper B.B., Dose J.J. & Williams J.E., 1997. Stream Restoration: Is Fisheries Biology Enough? Fisheries, 22(5) : 6-11.

Abstract : The fisheries profession is playing a key role in planning and implementing stream restoration projects throughout the world. To date, however, few examples exist of effective stream restoration programs or projects. One of the primary reasons stream restoration projects have not succeeded has been that projects are implemented on a small-scale, site-specific basis. We suggest that stream restoration would have a greater chance of succeeding if planned and implemented at a watershed scale. To do this, stream restoration projects must be expanded beyond instream work to include modification of upslope and riparian conditions that causes stream habitats to decline. In addition, planning for stream restoration at the watershed scale must include other disciplines that better understand these upslope watershed processes.

- 182 - Roper B.B., Konnoff D., Heller D. & Wieman K., 1998. Durability of Pacific Northwest Instream Structures Following Floods. North American Journal of Fisheries Management, 18(3) : 686-693.

Abstract.: The durability of 3,946 instream structures in 94 streams that had floods with return intervals exceeding 5 years were assessed. Overall structure durability (defined as the degree to which a structure remained at its original location) was high; less than 20% of the sampled structures had been removed from the site of original placement. The magnitude of flood events had a significant effect on structure durability with higher magnitude floods reducing durability. Stream order also affected structure durability; structures in large streams were 20 times more likely to have been removed from the site of original placement than structures in small streams. Other conditions that affected structure durability included location of the structure within the stream channel, whether the structure was anchored or not, structure material, and upslope landslide frequency. Instream structures are most appropriate when used as short-term tools to improve degraded stream conditions while activities that caused the habitat degradation are simultaneously modified. When instream structures are part of a properly sequenced watershed restoration strategy, they can improve habitat conditions through a range of flow conditions including large floods.

- 183 - Rosi-Marshall E.J., Moerke A.H. & Lamberty G.A., 2006. Ecological Responses to Trout Habitat Rehabilitation in a Northern Michigan Stream. Environmental Management, 38(1) : 99-107.

Keywords : Salmonidae • restoration • organic matter • macroinvertebrates • periphyton.

Abstract : Monitoring of stream restoration projects is often limited and success often focuses on a single taxon (e.g., salmonids), even though other aspects of stream structure and function may also respond to restoration activities. The Ottawa National Forest (ONF), Michigan, conducted a site-specific trout habitat improvement to enhance the trout fishery in Cook's Run, a 3rd-order stream that the ONF determined was negatively affected by past logging. Our objectives were to determine if the habitat improvement increased trout abundances and enhanced other ecological variables (overall habitat quality, organic matter retention, seston concentration, periphyton abundance, sediment organic matter content, and macroinvertebrate abundance and diversity) following rehabilitation. The addition of skybooms (underbank cover structures) and k-dams (pool-creating structures) increased the relative abundance of harvestable trout (>25 cm in total length) as intended but not overall trout abundances. Both rehabilitation techniques also increased maximum channel depth and organic matter retention, but only k-dams increased overall habitat quality. Neither approach significantly affected other ecological variables. The modest ecological response to this habitat improvement likely occurred because the system was not severely degraded beforehand, and thus small, local changes in habitat did not measurably affect most physical and ecological variables measured. However, increases in habitat volume and in organic matter retention may enhance stream biota in the long term.

- 184 - Ruiz-Jaen M.C. & Aide T.M., 2005. Restoration Success : How Is It Being Measured? Restoration Ecology, 13(3) : 569–577.

Abstract : The criteria of restoration success should be clearly established to evaluate restoration projects. Recently, the Society of Ecological Restoration International (SER) has produced a Primer that includes ecosystem attributes that should be considered when evaluating restoration success. To determine how restoration success has been evaluated in restoration projects, we reviewed articles published in *Restoration Ecology* (Vols. 1[1]–11[4]). Specifically, we addressed the following questions: (1) what measures of ecosystem attributes are assessed and (2) how are these measures used to determine restoration success. No study has measured all the SER Primer attributes, but most studies did include at least one measure in each of three general categories of the ecosystem attributes: diversity, vegetation structure, and ecological processes. Most of the reviewed studies are using multiple measures to evaluate restoration success, but we would encourage future projects to include: (1) at least two variables within each of the three ecosystem attributes that clearly related to ecosystem functioning and (2) at least two reference sites to capture the variation that exist in ecosystems.

- 185 - Rumps J.M., Katz S.L., Barnas K., Morehead M.D., Jenkinson R., Clayton S.R. & Goodwin P., 2007. Stream Restoration in the Pacific Northwest: Analysis of Interviews with Project Managers. Restoration Ecology, 15(3) : 506-515.

Abstract : Hundreds of millions of dollars per year are spent on river restoration in the Pacific Northwest (PNW), but little is known about the effectiveness of this effort. To help address this gap, we analyzed a database containing 23,000 projects at 35,000 locations in the region. We selected a subset of these projects for interviews using a survey instrument developed by a national team of scientists. In total, 47 project contacts in the PNW were interviewed to learn from the individuals directly involved in restoration. At least one-third of the projects surveyed (34%) did not conduct sufficient monitoring to evaluate effectiveness. More than two-thirds (70%) of all respondents reported their projects were successful, but 43% either have no success criteria or are unaware of any criteria for their project. Although almost two-thirds (66%) of respondents anticipate a need for ongoing project maintenance, less than half (43%) have maintenance funds available. These findings suggest that establishing a connection between effectiveness monitoring and project implementation is not a usual component of project design. Consequently, we can only assess the benefits in a few isolated projects and cannot quantify the cumulative benefits of restoration on a larger scale. These findings highlight

the need for (1) planning prior to implementation of restoration projects that accounts for monitoring design; (2) coordinated effectiveness monitoring to assess cumulative effects of restoration; and (3) management and maintenance of projects based on real measures of project performance.

- 186 - Ryder D.S. & Miller W., 2005. Setting Goals and Measuring Success: Linking Patterns and Processes in Stream Restoration. Hydrobiologia, 552(1) : 147-158.

Keywords : restoration • ecosystem structure • ecosystem function • river • biofilm • DOC.

Abstract : Successful stream restoration requires the setting of appropriate goals and an ability to measure restoration success using quantitative ecological indicators. At present, a dichotomy exists between the setting of restoration goals to enhance ecosystem 'processes' or 'functions' such as sustainability, and measuring the success of these goals using 'patterns' or 'structural' ecosystem attributes. The presence of a structural facade may be no indication of a viable ecosystem as this requires evaluation of whether key ecosystem processes have been restored and whether the system is ecologically sustainable. We briefly discuss the benefits and drawbacks associated with setting restoration goals and measuring their success based on ecosystem patterns and processes. Two case studies are provided based on measurements of biofilm chlorophyll *a* and Dissolved Organic Carbon (DOC) to debunk the myth that these structural variables can be used as surrogates for ecosystem processes of productivity and respiration in rivers. We suggest that the discipline of restoration ecology will benefit and grow from a greater appreciation of the functional role of biological communities within stream ecosystems, and from targeting some restoration towards the re-establishment of structurally significant species and functionally significant processes. This approach to stream restoration with a well-founded conceptual base and defined scientific and management goals should expand our knowledge of stream function and contribute to the effective restoration of stream systems.

- 187 - Sarriquet P.E., Bordenave P. & Marmonier P., 2007. Effects of bottom sediment restoration on interstitial habitat characteristics and benthic macroinvertebrate assemblages in a headwater stream. River Research and Applications, 23(8) : 815-828.

Keywords : river • agriculture • sediment clogging • hyporheic zone • drought.

Abstract : The restoration of in-stream habitats by structural improvement of stream beds is more and more frequent, but the ecological consequences of such works are still little known. We have examined the influence of the deposit of a 15 cm gravel layer over the stream bottom on the chemical characteristics of the interstitial water, the sediment grain size and the composition of the benthic assemblages. We have compared a restored reach to an upstream control over three years and at three seasons each year. Dissolved oxygen, ammonium, nitrite and nitrate contents were measured in both surface and interstitial (-15 cm deep) waters, together with the depth of anoxia estimated using wooden stakes and fine sediment content at the surface. During the same period and seasons, benthic invertebrates were sampled at five points in each reach. The restoration induced an increase in vertical exchanges of water between surface and interstitial habitats, with an increase in the depth of hypoxia. Changes were observed in the composition of invertebrate communities, but not in the density or in the taxonomic richness of assemblages. These changes in assemblages were fragile: a local disturbance (such as a drying period) diminished the beneficial effect of the restoration with the disappearance of several organisms. The viability of such restoration works may be associated with catchment management designed to reduce fine sediment inputs to the river.

- 188 - Saunders J.W. & Smith M.W., 1962. Physical Alteration of Stream Habitat to Improve Brook Trout Production. Transactions of the American Fisheries Society, 91(2) : 185-188.

Abstract : Thirteen dams, twelve deflectors, and several covers were constructed in a 450-yard section of Hayes Brook, Prince Edward Island, to create suitable hiding places for brook trout, Salvelinus fontinalis (Mitchill). In the following year the standing crop of fingerlings (age 0) was above average. The numbers of age I and older trout were approximately doubled. The alterations had no noticeable effect on the growth of trout.

- 189 - Schmetterling D.A. & Pierce R.W., 1999. Success of Instream Habitat Structures After a 50-Year Flood in Gold Creek, Montana. Restoration Ecology, 7(4) : 369-375.

Abstract : Gold Creek, in western Montana, lost complexity and diversity of fish habitat following riparian logging activities, removal of instream wood, and subsequent scouring. In the 4.8-km study area, the stream was almost totally void of large woody debris (4.2 pieces/km) and associated pools (1.3 pools/km). We constructed 66 structures made of natural materials (rock and wood) that resulted in 61 new pools in the study area in an attempt to restore salmonid habitat in the fall of 1996. An estimated 50-year recurrence interval flood occurred in the following spring. Of the original 66 structures, 55 (85%) remained intact and stable. Laterally confined reaches retained significantly more pools than laterally extended reaches. Owing to a history of anthropogenic impacts in forested streams in the intermountain west, restoration efforts are needed. If instream structures are tailored to specific morphologic channel types, fish habitat restoration can be successful and withstand major floods.

- 190 - Schmetterling D.A., Clancy C.G. & Brandt T.M., 2001. Effects of Riprap Bank Reinforcement on Stream Salmonids in the Western United States. Fisheries, 26(7) : 6-13.

Abstract : Angular rock riprap is used to reduce riverbank erosion in developed riparian corridors. We reviewed peer reviewed as well as non-refereed literature to determine the effects of riprap on salmonid habitat and populations and to identify areas for future (applied) research. Although commonly used to armor banks, riprap affects salmonid populations and stream function. Riprap may provide habitat for juvenile salmonids and bolster densities on reaches of streams that have been severely degraded. However, riprap does not provide the intricate habitat requirements for multiple age classes or species provided by natural vegetated banks. Streambanks with riprap have fewer undercut banks, less low-overhead cover and are less likely than natural stream banks to contribute large woody debris to the stream. Lateral streambank erosion is a natural process that occurs in many stream types. However, most valley-bottom stream types, which have the greatest tendency to laterally migrate, lie within developed corridors. Although permitting of individual projects may attenuate localized negative effects to streambanks, it may not effectively curtail cumulative effects to a watershed. Our review further demonstrated that the practice of riprapping banks goes against current practices and philosophies of stream renaturalization and impedes future restoration work. Future research should determine the true effects of riprap banks on salmonid densities, the use of soft techniques using for stabilizing banks on rivers, and the cumulative effects of riprap projects on watersheds and fluvial processes. We foresee a continued struggle for resource managers trying to maintain natural fluvial processes while protecting public infrastructure and private property from those same processes.

- 191 - Schwartz J.S.& Herricks E.E., 2007. Evaluation of pool-riffle naturalization structures on habitat complexity and the fish community in an urban Illinois stream. River Research and Applications, 23(4) : 451-466.

Keywords : naturalization • stream restoration • urban streams • habitat instream structures • ecohydraulics • bioassessment • fish.

Abstract : Urbanization and its associated stressors such as flow alteration, channel modification and poor water quality is a leading cause of ecological degradation to rivers and streams. Driven by public concern to address this issue, there has been a dramatic increase in urban restoration projects since 1990 using in-stream structures. Attempts at restoring the ecological condition of urban streams using structures have produced varied results, but projects do not often meet planned ecological goals. A major challenge to improving the ecological health of urban streams is to better understand how to incorporate ecological assessments into a "restoration" design framework with reasonable expectations for ecological recovery. A naturalization design framework was used in a project on a 0.62-km reach of the North Branch of the Chicago River in Northbrook, Illinois. Initial surveys of channel morphology, habitat and biota identified poor pool-riffle bed structure and fish biodiversity, which became the basis for research and development of a pool-riffle structure specifically designed for constrained, low-gradient channels. Habitat and fish surveys were conducted pre- and post-construction. The project improved mesohabitat structure, and fish abundance, and biomass and diversity were greater for 2 years following construction (2002-2003) compared to 3 years prior to

construction (1999-2001). However, the improved fish metrics were in the low range when compared to rural streams in the same ecoregion, and the fish community consisted primarily of tolerant, slow-water species. Absent were intolerant and riffle dwelling species, such as insectivorous cyprinids and darters. Assessment of pre- and post-project ecological condition and the use of species information provided a basis for ecologically informed design and expanded our understanding of the limitations to restoring urban streams.

- 192 - Scruton D., 1996. Evaluation of the construction of artificial fluvial salmonid habitat in a habitat compensation project, Newfoundland, Canada. Regulated Rivers : Research and Management, 12(2-3) : 171-183.

Keywords : artificial habitats • salonids • habitat compensation.

Abstract : In 1987, the provincial transportation agency in Newfoundland, Canada requested approval from the Canadian Department of Fisheries and Oceans (DFO) to destroy a 162 m section of fluvial salmonid habitat to accommodate highway construction. The DFO's *Policy for the Management of Fish Habitat* required the proponent to compensate for this habitat loss through the construction of a replacement section of stream. The results are presented from a research programme to evaluate the success of this project focusing on: (1) considerations in the design and construction of the replacement habitat; (2) a comparison of key habitat attributes between the destroyed stream section and the compensatory habitat; and (3) the utilization of the compensatory habitat by resident fish. The results of the study indicate an increase in habitat area of 125 m^2 (23%) over the 162 m section of stream habitat lost due to construction, primarily related to the increase in thalweig length (20% increase) resulting from designed sinuosity in the compensatory habitat. Habitat design increased the amount and proportion of pool habitat to benefit the primary resident species, brook trout (*Salvelinus fontinalis*) and resulted in a 134% increase in pool quantity (increase of 98 m^2), a 281% increase in pool volume (31.06 m^3), a 223% increase in the pool to riffle ratio and a 29% increase in the mean depth. Fish biomass, after an initial decrease after construction (1991), increased to the highest level during the study (93.5 g per 100 m^2 unit) in 1993, a 2.1-fold increase over the average pre-construction biomass. A corresponding decrease in salmonid densities was evident, primarily reflecting a shift in use from young of the year (YOY or 0 +) Atlantic salmon (*Salmo salar*) to larger, older brook trout in response to desired habitat features. Using biomass as an indicator of "productive capacity" and considering the increase in habitat quantity, there was a 2.58-fold increase in productive capacity over the stream lost due to highway construction and, in the context of DFO's habitat policy, compensation has resulted in a "net gain" in habitat.

- 193 - Scruton D.A., Anderson T.C. & King L.W., 1998. Pamehac Brook: A case study of the restoration of a Newfoundland, Canada, river impacted by flow diversion for pulpwood transportation. Aquatic Conservation: Marine and Freshwater Ecosystems, 8(1) : 145-157.

Abstract : In the early 1970s, dams were constructed in the upper reaches of Pamehac Brook, Newfoundland, Canada, and the headwaters of the system were diverted into the main stem of the Exploits River to facilitate waterborne transport of logs to a pulp and paper mill. This de-watered 12 km of high quality brook trout (*Salvelinus fontinalis*) and Atlantic salmon (*Salmo salar*) rearing and spawning habitat. In 1989, a project was conceived to address the man-made obstructions to fish migration and restore (re-water) the lower reaches of Pamehac Brook. This project was pursued as a partnership between the Environment Resources Management Association (a local conservation group), Abitibi-Price Inc. (a pulp and paper company), the Environmental Partners Fund (of Environment Canada), and the Canadian Department of Fisheries and Oceans. The restoration of Pamehac Brook in August 1990 included replacement of the control dams with bridges and culverts and removal of the diversion dyke to re-water the stream. Habitat surveys conducted before and after the project indicated a gain in fluvial habitat of 450 units (1 unit = 100 m super(2)), a 62% increase, through re-watering of the stream channel. Improved access was provided to 175 habitat units in the headwaters which had previously been obstructed. Population estimates of juvenile fish from electro fishing surveys were used to document the rate of recolonization of the re-watered habitat and to estimate the increase in fish production potential. Results suggested limited response by fish populations in the initial 2 years after restoration. Electrofishing results in 1996 indicated a dramatic increase in biomass of larger juvenile salmon and trout (> 0+), attributable to the increased habitat

area and altered microhabitat conditions, in part, related to creation of standing water areas from beaver dams. Population estimates in 1996, in consideration of available fluvial habitat, indicated a production potential of juvenile fish of 330 kg, an 18-fold increase from pre-project estimates.

- 194 - Scruton D.A., Clarke K.D., Roberge M.M., Kelly J.F. & Dawe M.B., 2005. A case study of habitat compensation to ameliorate impacts of hydroelectric development: effectiveness of re-watering and habitat enhancement of an intermittent flood overflow channel. Journal of Fish Biology, 67(sb) : 244–260.

Abstract : Development of the Rose Blanche River, insular Newfoundland, Canada, for hydroelectricity resulted in destruction of fluvial habitat and habitat compensation was required to achieve 'no net loss'(NNL) of habitat productive capacity. The preferred compensation alternative involved modification of a 1·2 km long natural high flow, flood bypass channel, wetted only during peak snow melt events. The channel consisted of 99·6 units (100 m^2) of habitat and was modified, with hydraulic control structures, to ensure a constant regulated flow. Physical enhancement included addition of spawning gravels, bank stabilization, protection dykes to prevent flooding and installation of low head barriers to create pools. A 3 year study (2000–2002) was undertaken to assess: (1) habitat stability in the channel, (2) re-population of the compensatory channel, (3) biological characteristics of fishes utilizing the channel and (4) movement and migration between the compensatory channel and the main river. Study results indicated evolution of meso-habitat characteristics due to geomorphological and hydrological factors, with distribution of spawning gravels and increased input of organic matter. The channel was utilized preferentially by brook trout *Salvelinus fontinalis*, with a mix of size and age classes, indicating habitat use by all life stages. Total fish biomass over 3 years increased in the compensation channel while it decreased in the river main stem. Young-of-the-year density was strong for both brook trout and Atlantic salmon *Salmo salar* in 2001 and 2002 suggesting good spawning and incubation conditions. Year class strength was less in the main river indicating differential (improved) survival in the compensatory habitat. Tag returns provided little evidence of site fidelity for both species suggesting considerable movement within the channel and possibly between the main river and channel. Habitat compensation effectiveness, in terms of NNL, determined that fish production in the compensatory channel achieved 69, 92 and 128% of lost production in 2000, 2001 and 2002, respectively. Fish production increased each year after development and NNL was achieved by the third year. The NNL was achieved in the compensatory channel which contained 100 units as opposed to the 570 units destroyed, a 1 : 5·7 ratio. The results of the study indicated that both habitat area and a measure of habitat productive capacity need to be considered in planning and assessing habitat compensation projects.

- 195 - Sear D.A., 1994. River restoration and geomorphology. Aquatic Conservation : Marine and Freshwater rehabilitation, 4(2) : 169-177.

Abstract : The restoration or rehabilitation of rivers is currently an expanding area of investment by public water management bodies in the USA and EC. This position has developed from the rapid growth in environmental (and particularly water) awareness, the rise of accountability for environmental degradation within the legislative framework of water institutions and the move away from agricultural over-production towards sustainable development.
The restoration process has been pioneered primarily by aquatic ecologists and landscape designers working in conjunction with civil engineers. Geomorphology, the science of landform development, has much to offer, but at present the contributions are often superficial, concentrating on the scaling and siting of instream fluvial features. This paper argues that it is essential to incorporate the broader geomorpho-logical wisdom at the design stage so that restoration schemes will be sustainable in the longer term.

- 196 - Shetter D.S., Clark O.H. & Hazzard S., 1949. The Effects of Deflectors in a Section of a Michigan Trout Stream. Transactions of the American Fisheries Society, 76(1) : 248-278.

Abstract : The changes in angling produced by current deflectors in a 1,605-foot section of Hunt Creek, a Michigan brook trout (*Salvelinus fontinalis*) stream, were studied over an 8-year period, 3 years before and 5 years after placement of the devices. Data on changes in the physical character of the stream, the fish population, and the bottom food supply also are presented for 1 year before and 3 years after installation of deflectors. The methods used to measure these various changes are given.
Installation of 24 pool-forming deflectors raised the number of good pools from 9 to 29, increased the average pool depth by 6 inches, and exposed additional gravel without significantly changing the average stream depth over the entire section. Preliminary and unpublished bottom-food studies indicated a decrease in total number and volume of all organisms but an increase in forms found most frequently in trout stomachs. Fish-population studies demonstrated slight increases in the number of smaller trout present after the addition of deflectors, attended by a slight decrease in average size. Average creel-census figures for the 3 years prior to stream improvement and the 5 years after show an increase after improvement of 120 percent in the total catch and of 46 percent in pounds caught per hour coincident with a 64 percent increase in angling pressure. It was demonstrated that migration into the section improved was not responsible for the increases noted, also that bordering sections failed to have fishing comparably good to that produced in the improved section. It was concluded that the improvement in brook trout fishing in the experimental section was the result of an increase in number, size, and depth of pools created by installation of current deflectors.

- 197 - Shields F.D. & Hoover J.J., 1991. Effects of channel restabilization on habitat diversity, twentymile creek, Mississippi. Regulated River : Research & Management, 6(3) : 163-181.

Keywords : channel instability • channelization • fish • species diversity • habitat diversity • erosion • rivers • nickpoint • knickpoint-grade control structure • streambank protection • sedimentation.

Abstract : Twentymile Creek, a sand-bed stream draining a 450 km^2 catchment in northeast Mississippi, was channelized prior to 1910, in 1938, and in 1966. Straightening and enlargement in 1966 was followed by channel instability - rapid bed degradation (2-4 m) and cross-section enlargement by 1.4 to 2.7 times. Grade control structures (GCS) (weirs with stoneprotected stilling basins) and various types of streambank protection were constructed along the channel in the early 1980s to restore stability. Other investigators have suggested that habitat recovery in incised, channelized streams is facilitated by construction of GCS because they create stable scour holes and promote natural formation of a low-flow channel flanked by vegetated berms. Effects of restabilization of Twentymile Creek on aquatic habitats were assessed in four ways. The fraction of the bank line covered by woody vegetation was mapped from aerial photographs taken in 1981 and 1985; physical habitat (depth, velocity, substrate, and cover) and fishes were sampled at base flow; and the existence and size of a low-flow channel was ascertained from cross-section surveys taken in 1980 and 1989. Woody vegetation, physical aquatic habitat, and fishes were also sampled from Mubby-Chiwapa Creek, a similar-sized unstable channel with no GCS. Physical habitat variables and fishes were sampled concurrently at five stations on Twentymile Creek, and four stations on Mubby-Chiwapa. Four of the five Twentymile stations were either above or below a GCS. Bank-line woody vegetation cover increased 8 per cent between 1981 and 1985 along Twentymile Creek but was stable along Mubby-Chiwapa. Reaches above and below GCS were deeper with slower current velocities than elsewhere. Mean Shannon diversity indices based on physical data were similar for both streams, but were 58 per cent higher for stations immediately above and below GCS than for other stations. Since construction of the GCS and bank protection measures, longitudinal berms have formed within the enlarged Twentymile Creek channel, creating a low-flow channel. Low-flow channel capacity was equivalent to a mean daily discharge equalled or exceeded 30 per cent of the time, and was considerably lower than the effective discharge. Differences in aquatic habitat diversity among the stations sampled were primarily due to the scour holes below the GCS and the low-flow channel. Thirty-nine fish species were collected from Twentymile Creek, but only 22 from Mubby-Chiwapa. Fourteen species were collected exclusively at GCS. Principal component analyses of the abundance of the eight numerically dominant fish species indicated similar faunas at most stations, but Twentymile Creek GCS stations were faunistically distinct. Abundance of several of the numerically dominant species was positively influenced by greater depths and lower velocities found near Twentymile GCS. The mean fish diversity

index for Twentymile Creek was 29 per cent higher than for Mubby-Chiwapa, and fish diversity was positively correlated with substrate diversity and mean depth.

- 198 - Shields F.D., Cooper C.M. & Knight S.S., 1993. Initial habitat response to incised channel rehabilitation. Aquatic Conservation : Marine and Freshwater rehabilitation, 3(2) : 93-103.

Abstract :

1- Incised stream channel aquatic habitats typically are severely degraded. After the primary knickpoints or knickzones have passed, base flows are limited to shallow channels flanked by sandy berms within the enlarged high-flow channel. Riparian vegetation, woody debris and pool habitat are in short supply, and stream systems become disengaged from their floodplains.

2- We hypothesized that habitat recovery might be accelerated in channels that have incised and are regaining equilibrium through deposition of sandy berms by placing rock spurs in the channel and by planting woody vegetation on the berms. On the basis of literature review and a pilot study, planting designs were developed for a large-scale field experiment: 2550 1.5 m long cuttings of native willow (*Salix* spp.) 2-25 cm in diameter were planted 1-1.2 m deep along the base-flow channel of an incised stream. A ridge of stone was placed on the water side of the plantings, and 17 rock spurs were constructed by extending existing spur dikes from the opposite bank.

3- Woody cover along the treated bank increased from 38% to 66% of bankline after one growing season. Survival of individual plantings was reduced from an estimated 60% to an observed 34% by competition from the exotic kudzu vine, *Pueraria lobata.* Mean depth and mean scour hole depth, corrected for stage variation, increased 44% and 82%, respectively. Mean scour hole width increased 130%. The mean length of fish and the number of fish species approximately doubled, while the total weight of fish captured by a unit of sampling effort increased by an order of magnitude.

- 199 - Shields F.D., Cooper C.M. & Knight S.S., 1995. Experiment in Stream Restoration. Journal of Hydraulic Engineering, 121(6) : 494-502.

Abstract : Aquatic habitats in a deeply incised sand-bed channel were modified by adding 1,380 t of stone and planting dormant willow posts. Restoration structures (groin extensions and longitudinal toe protection) were designed as complements to existing channel stabilization works. Prior to restoration, base-flow aquatic habitats were characterized by uniform conditions, little woods debris or riparian vegetation, shallow depths, and sandy bed material. The stage-discharge relationship, channel geometry, and bed material size were unaffected by restoration, but the average depth of scour holes adjacent to extended groins increased from 32 cm to 72 cm, and pool habitat in the lower half of the study reach increased from 2.9% to 14% of water surface area. Median water depth at base flow increased from 9 cm to 15 cm. Woody vegetation cover on one side of the channel increased from 38% to 78%. Fish numbers tripled, median fish size increased by 50%, and the number of species increased from 14 to 19. Groin extensions experienced partial failure due to erosion of sand from underneath stones.

- 200 - Shields F.D., Knight S.S. & Cooper C.M., 1997. Rehabilitation of warmwater stream ecosystems following channel incision. Ecological Engineering 8(2) : 93-116.

Abstract : Presented is a case study of two streams (watershed size, 12 and 14 km^2) damaged by channel straightening and incision. One stream was stabilized using a metal sheet piling weir and dormant willow post planting, while the other was treated with a stone weir, stone toe bank protection and willow sprout planting. Fishes and their physical habitats were monitored for 1–2 years before construction and two to three years afterward. Willow planting was not successful, so canopy, bank vegetation, and woody debris density were unchanged. Pool habitat area increased from less than 5% to more than 30% of the total aquatic area. Fish species richness and diversity were unchanged, but species composition shifted away from patterns typical of shallow, sandy runs toward pool-dwelling types, becoming more similar to a nearby lightly-degraded reference site. Median lengths of selected centrarchids increased following rehabilitation. Physical and biological response were more persistent

for the stream treated with the stone weir and bank toe protection, possibly because the stone toe produced a more uniform longitudinal distribution of cover and pool habitats than the single weir.

- 201 - Shields F.D., Knight S.S. & Cooper C.M., 1998a. Rehabilitation of aquatic habitats in warmwater streams damaged by channel incision in Mississippi. Hydrobiologia, 382(1-3) : 63-86.

Keywords : stream restoration • fish • erosion • sediment • physical habitat.

Abstract : Channel incision has major impacts on stream corridor ecosystems, leading to reduced spatial habitat heterogeneity, greater temporal instability, less stream-floodplain interaction, and shifts in fish community structure. Most literature dealing with channel incision examines physical processes and erosion control. A study of incised warmwater stream rehabilitation was conducted to develop and demonstrate techniques that would be economically feasible for integration with more orthodox, extensively employed watershed stabilization techniques (e.g., structural bank protection, grade control structures, small reservoirs, and land treatment). One-km reaches of each of five northwest Mississippi streams with contributing drainage areas between 16 and 205 km2 were selected for a 5-year study. During the study two reaches were modified by adding woody vegetation and stone structure to rehabilitate habitats degraded by erosion and channelization. The other three reaches provided reference data, as two of them were degraded but not rehabilitated, and the third was only lightly degraded. Rehabilitation approaches were guided by conceptual models of incised channel evolution and fish community structure in small warmwater streams. These models indicated that rehabilitation efforts should focus on aggradational reaches in the downstream portions of incising watersheds, and that ecological status could be improved by inducing formation and maintenance of stable pool habitats.
Fish and physical habitat attributes were sampled from each stream during the Spring and Fall for 5 years, and thalweg and cross-section surveys were performed twice during the same period. Rehabilitation increased pool habitat availability, and made the treated sites physically more similar to the lightly degraded reference site. Fish communities generally responded as suggested by the aforementioned conceptual model of fish community structure. Species composition shifted away from small colonists (principally cyprinids and small centrarchids) toward larger centrarchids, catostomids, and ictalurids. Fish density and species richness increased at one rehabilitated site but remained stable at the other, suggesting that the sites occupied different initial states and endpoints within the conceptual model, and differed in their accessibility to sources of colonizing organisms. These experiments suggest that major gains in stream ecosystem rehabilitation can be made through relatively modest but well-designed efforts to modify degraded physical habitats.

- 202 - Shields F.D., Knight S.S. & Cooper C.M., 1998b. Addition of spurs to stone toe protection for warmwater fish habitat rehabilitation. Journal of the American Water Resources Association, Volume 34 Issue 6 Page 1427-1436, December 1998

Abstract : Longitudinal stone toe is one of the most reliable and economically attractive approaches for stabilizing eroding banks in incised channels. However, aquatic habitat provided by stone toe is inferior to that provided by spur dikes. In order to test a design that combined features of stone toe and spurs, eleven stone spurs were placed perpendicular to 170 m of existing stone toe in Goodwin Creek, Mississippi, and willow posts were planted in the sandbar on the opposite bank. Response was evaluated by monitoring fish and habitats in the treated reach and an adjacent comparison reach (willow post planting and standard toe without spurs) for four years. Furthermore, physical habitats within the treated reach were compared with seven reaches protected with standard toe on a single date three years after construction. Overall results indicated that spur addition resulted in modest increases in baseflow stony bankline, water width and pool habitat availability, but had only local effects on depth. These relatively small changes in physical habitat were exaggerated seasonally by beaver dams that appeared during periods of prolonged low flow in late Summer and Autumn. Physical changes were accompanied by shifts in fish species composition away from a run-dwelling assemblage dominated by large numbers of cyprinids and immature centrarchids toward an assemblage containing fewer and larger centrarchids. Biological responses were at least partially due to the effects of temporary beaver dams.

- 203 - Shields F.D., Knight S.S., Morin N. & Blank J., 2003. Response of fishes and aquatic habitats to sand-bed stream restoration using large woody debris. Hydrobiologia, 494(1-3) : 251-257.

Keywords : stream restoration • large woody debris • fish • erosion • sediment • physical habitat.

Abstract : Effects of habitat rehabilitation of Little Topashaw Creek, a sinuous, sand-bed stream draining 37 km^2 in northwest Mississippi are described. The rehabilitation project consisted of placing 72 large woody debris structures along eroding concave banks and planting 4000 willow cuttings in sandbars. Response was measured by monitoring flow, channel geometry, physical aquatic habitat, and fish populations. Initially, debris structures reduced high flow velocities at concave bank toes, preventing further erosion and inducing deposition. Physical response during the first year following construction included creation of sand berms along eroding banks and slight increases in base flow water width and depth. Fish collections showed assemblages typical of incising streams within the region, but minor initial responses to debris addition were evident. Progressive failure of the structures and renewed erosion were observed during the second year after construction.

- 204 - Shields Jr, F.D., Knight, S.S. 2004. Ten years after: retrospective evaluation of a stream habitat restoration project. American Society Of Civil Engineers Water Resources Conference Proceedings. p. 38-50.

Abstract : Long-term assessments of ecosystem rehabilitation project effects are rare. Herein we describe a study of the Hotophia Creek rehabilitation project in northwest Mississippi. Fish and physical aquatic habitat data were collected for one year prior to construction of a one-km long stream habitat rehabilitation project in 1992. Habitat rehabilitation consisted of extending existing stone spurs, placing stone toe, and planting willow cuttings. Post-construction monitoring was conducted for the four years following construction, and at 10 years following construction. Parallel monitoring was conducted on an untreated reference stream and on untreated reaches upstream on Hotophia Creek. Effects of rehabilitation on habitat and fish communities were found to be positive in both the short and long term. For example, after 10 years, mean water depth in the reach subjected to rehabilitation was more than twice as great as for untreated reaches upstream. Woody riparian vegetation more than doubled and large woody debris density increased by an order of magnitude in both treated and untreated streams. Fish populations shifted away from domination by large numbers of small, opportunistic generalists and toward dominance by large-bodied, pool-dwelling species typical of more pristine streams. Prior to rehabilitation, 51% of the fish captured were cyprinids (minnows), while 10 years later 61% of the fish captured were centrarchids (sunfishes).

- 205 - Shields F.D., Knight S.S. & Cooper C.M., 2006a. Incised stream physical habitat restoration with stone weirs. Regulated River : Research & Management, 10(2-4) : 181-198.

Keywords : physical habitat restoration • incised streams • stone weirs.

Abstract : The initial results are described of the restoration of 1 km long reach of Goodwin Creek, a channelized sand and gravel bed warm-water stream draining a 21 km^2 lowland catchment in north-west Mississippi. Although a series of grade control weirs and bank protection works had been constructed before restoration, sediment production from channel erosion remained high (> 1200 t km^{-2} y^{-1}) and aquatic habitats were of poor value. At base flow, only 5-20% of the water area was classified as pool habitat (depth >30 cm and velocity <10 cm s^{-1}). Restoration works were designed to be compatible with existing channel stabilization works and economic critera. Stone was added to extend the existing groynes across the base flow channel to create 18 small weirs. The effects of restoration were quantified by collecting fish and physical habitat data semi-annually for two years before and during the first year after restoration from the restored reach and from two reference streams. Restoration increased pool habitat availability, overall physical heterogeneity, riparian vegetation, shade and woody debris density. After restoration, mean width, depth and velocity exhibited changes of +56, +150 and -56%, respectively, despite discharge levels that averaged 43% lower during data collection periods. The pool area increased to 72% of the water area. Bed types became more heterogeneous, with larger fractions of clay, debris and riprap, and less sand and gravel. The fish response to restoration measures was modest, but distinct. Before restoration cyprinids and centrarchids comprised 74 and 11%, respectively, of the numerical catch, but 32 and

55% after restoration. Fish species composition and relative abundance after restoration were slightly more similar to that of the non-incised reference site than before restoration. The median lengths of five selected fish species were greater after restoration, but were unchanged at reference sites.

- 206 - Shields F.D., Knight S.S. & Stofleth, 2006b. Large wood addition for aquatic habitat rehabilitation in an incised, sand-bed stream, Little Topashaw Creek, Mississippi. River Research and Applications, 22(7) : 803-817.

Keywords : stream restoration • large woody debris • fish • erosion • sediment • physical habitat.

Abstract : Large wood (LW) is a key component of stream habitats, and degraded streams often contain little wood relative to less-impacted ones. Habitat rehabilitation and erosion control techniques that emphasize addition of natural wood in the form of individual elements or structures are increasingly popular. However, the efficacy of wood addition, especially in physically unstable, warmwater systems is not well established. The effects of habitat rehabilitation of Little Topashaw Creek, a sinuous, sand-bed stream draining 37 km^2 in northwest Mississippi are described herein. The rehabilitation project consisted of placing 72 LW structures along eroding concave banks of a 2-km reach and planting 4000 willow cuttings in sandbars opposite or adjacent to the LW structures. Response was measured by monitoring flow, channel geometry, physical aquatic habitat and fish populations in treated and untreated reaches for 2 years before and 4 years after rehabilitation. Initially, LW structures reduced high flow velocities at concave bank toes. Progressive failure of the LW structures and renewed erosion began during the second year after rehabilitation, with only 64% of the structures and about 10% of the willow plantings surviving for 3 years. Accordingly, long-term changes in physical habitat attributable to rehabilitation were limited to an increase in LW density. Fish biomass increased in the treated reach, and species richness approximately doubled in all reaches after rehabilitation, suggesting the occurrence of some sort of stressful event prior to our study. Fish community composition shifted toward one typical of a lightly degraded reference site, but similar shifts occurred in the untreated reaches downstream, which had relatively high levels of naturally occurring LW. Large wood is a key component of sand-bed stream ecosystems, but LW addition for rehabilitation should be limited to sites with more stable beds and conditions that foster rapid woody plant colonization of sediment deposits.

- 207 - Shuler S.W. & Nehring R.B., 1993. Using the physical habitat simulation model to evaluate a stream habitat enhancement project. Rivers, 4(3) : 175-193.

Abstract : Adult and juvenile brown trout (Salmo trutta) habitat suitability criteria (HSC) curves developed in the Rio Grande and South Platte rivers, Colorado, were used in the Physical Habitat Simulation (PHABSIM) model to evaluate habitat (weighted usable area; WUA) created by enhancement structures in the Rio Grande River. Although HSC curves for the two rivers produced slightly different estimates of WUA at a single study site and flow, WUA relations among study sites were similar over a wide range of flows. For both HSC curve sets, adult trout WUA and density were positively correlated across 10 study sections in each of 3 years (1989 through 1991). Beyond age-3, the significance level increased with age. Correlations of juvenile brown trout density and WUA were not significant. Composite suitability indexes (water depth, velocity, and cover) for individual cells were stratified into optimal, acceptable, and unsuitable habitat ranges. Observation by snorkeling and angling revealed that adult and juvenile trout preferred optimal and acceptable habitat zones and avoided unsuitable habitat during day and night across a range of flows. Habitat quality and quantity differed among structures over a range of flows. In riffle areas, greater levels of habitat enhancement increased preferred habitat availability according to the PHABSIM model. Moreover, densities of trout greater than or equal to 35 cm increased significantly after the placement of habitat enhancement structures.

- 208 - Shuler S.W., Nehring R.B. & Fausch K.D., 1994. Diel habitat selection by brown trout in the rio grande river, Colorado, after placement of boulder structures. North American Journal of Fisheries Management, 14(1) : 99-111.

Abstract : Brown trout *Salmo trutta* distribution and microhabitat use were measured in 10 study sections of the Rio Grande River, Colorado, where three types of structures made from large boulders had previously been placed. On average, 65% of the adult brown trout and 69% of the juvenile brown trout observed were holding positions near structures. Brown trout used primarily wingdams, midchannel boulder clusters, and natural bank cover, and avoided single boulders and areas with no structures. Juvenile and adult brown trout showed a significant preference for wing-dams during the day at both high and low flows, but adults shifted from wingdams to midchannel boulder clusters at night during low flows. Distributions of water depth and mean water velocity at positions used by brown trout differed significantly between age-classes but were generally not significantly different at high versus low flows, between day and night, or between fish using and not using structures. Results suggest that brown trout selected feeding sites primarily based on water velocity and cover, and that boulder structures provided more locations that were energetically favorable for brown trout.

- 209 - Slawski T.m. & Ehlinger T.J., 1998. Fish Habitat Improvement in Box Culverts: Management in the Dark?. North American Journal of Fisheries Management, 18(3) : 676-685.

Abstract : The effects of limestone baffles on the hydrological and fish assemblage characteristics of two separate 2.4-m-wide box culverts along the course of a cold headwater trout stream in southeastern Wisconsin were examined. Alternating limestone baffles were placed along the upstream half of one culvert, and the adjacent downstream half was left unmanipulated. The effects of the baffles on water depth, velocity, substrate, and fish abundance were assessed by comparing sites (control versus manipulated) among years from 1994 to 1996 (5, 18, and 32 months after manipulation). The manipulated section exhibited greater mean and variance in depth, velocity, and substrate composition, resulting in a more dynamic and natural stream channel compared with the control reach. Fish abundance and species diversity were greater within the manipulated section than in the control. In addition, average total fish species abundance and diversity within the section with the experimental baffle were comparable with adjacent sites in the natural stream directly upstream and downstream from the culvert. Baffles were placed along the entire length of a second culvert, which resulted in stream channel and fish assemblage characteristics similar to those observed in the manipulated section of the first culvert. These results demonstrate that manipulations within box culverts can increase habitat heterogeneity and enhance resident stream fish abundance and diversity. This alternate baffle design offers managers an inexpensive way to increase fish abundance and diversity and to help mitigate the loss of habitat caused by culverts in stream systems

- 210 - Society for Ecological Restoration International Science & Policy Working Group, 2004. The SER International Primer on Ecological Restoration. www.ser.org & Tucson : Society for Ecological Restoration International.

- 211 - Spänhoff B., Riss W., Jäkel P., Dakkak N. & Meyer E.I., 2006. Effects of an Experimental Enrichment of Instream Habitat Heterogeneity on the Stream Bed Morphology and Chironomid Community of a Straightened Section in a Sandy Lowland Stream. Environmental management, 37(2) : 247-257.

Keywords : habitat enrichment • woody debris • chironomid community • pupal exuviae • drift • stream restoration.

Abstract : A straightened stream stretch with poor habitat heterogeneity was divided into a “control” section with a low amount of submerged woody debris and an experimentally “wood-enriched” downstream section to study the effect of enhanced habitat diversity on the benthic invertebrate community. The downstream section was enriched by fixing 25 wood packages constructed from 9–10 branches on the stream bottom. Succession processes occurring in the two stream sections were compared by chironomid exuviae drift from July to November 2000 and from April to August 2001.

During the first sampling period, more drifting chironomid exuviae (medians of control vs. wood-enriched: 446 vs. 331, no significant difference) and total number of taxa (44 vs. 36, Wilcoxon signed-rank test $P = 0.019$) were recorded for the control section. Although species compositions of both stream sections were highly similar (Sørensen index: 0.83) the diversity in the wood-enriched section was distinctly lower compared to the control section (Shannon–Weaver index: 1.19 vs. 1.50). During the second sampling period, exuviae numbers remained higher in the control section (median: 326 vs. 166), but total numbers of taxa were nearly equal (51 vs. 49), as well as species diversity (Shannon–Weaver index: 1.67 vs. 1.64). The lower chironomid diversity observed during the first sampling period coincided with a gradual but significant change of the streambed morphology in the wood-enriched section. There, the initially more U-shaped profile (V/U = 0.81 ± 0.37) had turned into a pronounced V shape (V/U = 1.14 ± 0.21), whereas the control section retained its unaltered U shape (V/U = 0.62–0.75). This small-scale study on experimental of woody debris in sandy lowland streams showed that the negative impact of increased hydraulic disturbance of the existing streambed more than outweighed any positive impact resulting from the increase in woody debris.

- 212 - Spanhöff B. & Arle J., 2007. Setting Attainable Goals of Stream Habitat Restoration from a Macroinvertebrate View. Restoration Ecology, 15(2) : 317-320.

Keywords : aquatic macroinvertebrates • habitat heterogeneity • invertebrate dispersal • stream recovery • stream restoration.

Abstract : Many efforts have been undertaken to reduce the impairment of stream ecosystems by wastewaters and other pollution, leading to a remarkable improvement of the water quality in most parts of Central Europe. Actually, the most severe disturbance to stream systems in Central Europe is the structural degradation of stream morphology. Restoration practices increasing the structural heterogeneity of formerly degraded stream sections are necessary to create new habitats at different scales that could provide habitat for a diverse invertebrate community. Increasing biodiversity of aquatic invertebrates strengthens the ecological integrity of streams and is therefore a desirable goal in stream restoration. Nevertheless, recent studies focusing on the effect of structural restoration of stream sections often displayed results that did not really met the preset goal of increasing invertebrate diversity. This might be due to sometimes severe disturbance caused by the restoration practice itself, impairing the established invertebrate community in the restored stream section. Additionally, the potential for immigration of new species into the restored stream section is often limited. Therefore, several important prerequisites must be accounted for in the planning of restoration practices to improve structurally degraded stream sections, when the goal of restoration is increasing invertebrate diversity.

- 213 - Streubel D.N. & Griffith J.S., 1993. Use of Boulder Pocket Habitat by Rainbow Trout (Oncorhynchus mykiss) in Fall River, Idaho. Great Basin Naturalist GRBNAR, 53(2) : 194-198.

Abstract : Abundance of rainbow trout (*Oncorhynchus mykiss*) in relation to characteristics of pockets created by boulders was studied in Fall River, southeastern Idaho. To determine depth and surface area of pockets most selected by rainbow trout, fish were counted by snorkeling, and pocket physical dimensions were measured. An electivity index defined habitat selection in the following terms: the most suitable habitat was at least 0.7 m maximum depth, not less than 0.5 m minimum depth, and at least 3 sq m in surface area. Some study reaches of Fall River had more suitable pockets available for trout than were being utilized.

- 214 - Sudduth E.B. & Meyer J.L., 2006. Effects of Bioengineered Streambank Stabilization on Bank Habitat and Macroinvertebrates in Urban Streams. Environmental management, 38(2) : 218-226.

Keywords : stream restoration • bioengineering • bank stabilization • bank habitat • macroinvertebrates • urban streams • Peachtree Creek.

Abstract : Non-structural streambank stabilization, or bioengineering, is a common stream restoration practice used to slow streambank erosion, but its ecological effects have rarely been assessed. We surveyed bank habitat and sampled bank macroinvertebrates at four bioengineered sites, an unrestored site, and a comparatively less-impacted reference site in the urban Peachtree-Nancy Creek catchment in Atlanta, GA, USA. The amount of organic bank habitat (wood and roots) was much higher at the reference site and three of the bioengineered sites than at the unrestored site or the other bioengineered site, where a very different bioengineering technique was used ("joint planting"). At all sites, we saw a high abundance of pollution-tolerant taxa, especially chironomids and oligochaetes, and a low richness and diversity of the bank macroinvertebrate community. Total biomass, insect biomass, and non-chironomid insect biomass were highest at the reference site and two of the bioengineered sites ($p < 0.05$). Higher biomass and abundance were found on organic habitats (wood and roots) versus inorganic habitats (mud, sand, and rock) across all sites. Percent organic bank habitat at each site proved to be strongly positively correlated with many factors, including taxon richness, total biomass, and shredder biomass. These results suggest that bioengineered bank stabilization can have positive effects on bank habitat and macroinvertebrate communities in urban streams, but it cannot completely mitigate the impacts of urbanization.

- 215 - Sudduth E.B., Meyer J.L. & Bernhardt E.S., 2007. Stream Restoration Practices in the Southeastern United States. Restoration Ecology, 15(3) : 573-583.

Keywords : channel reconfiguration • evaluation • in-stream habitat improvement • monitoring • riparian management • southeastern United States • stream restoration • water quality management.

Abstract : We collected information on 860 stream restoration projects in four states in the southeastern United States—Georgia, Kentucky, North Carolina, and South Carolina—to gain a better understanding of the practice of stream restoration in this area of high aquatic biodiversity and rapid metropolitan expansion. This was completed as a part of the National River Restoration Science Synthesis, with the larger goal of understanding the state of the science of stream restoration. Stream restoration project density, goals, and monitoring rates varied by state, although southeastern monitoring rates were higher than in other parts of the country. North Carolina had the most projects in the Southeast, of which 36% were monitored. In-depth phone interviews with project managers from a random subsample of projects provided insights into the process of stream restoration. Land availability was the most common basis for site prioritization, and 49% of projects involved mitigation. Although 51% of projects were associated with a watershed assessment, only 30% of projects were done as part of a larger plan for the watershed. Projects were monitored using physical (77% of monitored projects), chemical (36%), and biological (86%) variables, although many projects were planned and ultimately evaluated based on public opinion. Our results suggest that stream restoration in the southeastern United States is at an exciting point where better incorporation of a watershed perspective into planning and establishment and evaluation of stated, measurable success criteria for every project could lead to more effective projects.

- 216 - Suren A.M., Riis T., Biggs B.J.F., McMurtrie S. & Barker R., 2005. Assessing the effectiveness of enhancement activities in urban streams: I. Habitat responses. River Research and Applications, 21(4) : 381-401.

Keywords : urban streams • enhancement • riparian vegetation • habitat • hydraulics • sediments.

Abstract : Effects of stream enhancement on habitat conditions in five spring-fed urban streams in Christchurch, New Zealand, were investigated. Stream enhancement consisted of riparian planting at three sites, and riparian planting and channel modifications at two sites, where a concrete dish channel and a timber-lined channel were removed, and natural banks reinstated. Sites were surveyed

prior to enhancement activities and 5 years after, and changes in riparian conditions (composition, horizontal and vertical cover), instream conditions (bank modifications, inorganic and organic material on the streambed), and hydraulic conditions (wetted perimeter, cross-sectional area, depths and velocities) quantified. Enhanced sites generally had higher marginal vegetation cover, as well as increased overhanging riparian vegetation, reflecting planting of *Carex* sedges close to the water. Bed sediments changed at some sites, with the greatest change being replacement of a concrete channel with gravel and cobble substrate. Bryophyte cover declined at this site, reflecting loss of stable habitat where these plants grew. Bed sediments changed less at other sites, and cover of fine sediments increased in some enhanced sites, presumably from sediment runoff from nearby residential development. Filamentous algal cover decreased at one stream where shade increased, but increased in another stream where the removal of timber-lined banks and creation of a large pond decreased shade. Stream enhancement increased variability in velocity at three of the five sites, but overall changes to stream hydraulics were small. Although enhancement activities altered the physical conditions of the streams, major changes occurred only to riparian vegetation and bank conditions. Lack of other major changes to instream physical conditions most likely reflected the limited range of channel morphology alterations undertaken. Moreover, the flat topography of Christchurch and naturally low stream discharge further constrained changes to instream physical conditions from enhancement activities. Sediment inputs from continuing urban development also negated the effects of adding coarse substrates. These over-arching factors may constrain the success of future stream enhancement projects within Christchurch.

- 217 - Suren A. M. & McMurtrie S., 2005. Assessing the effectiveness of enhancement activities in urban streams: II. Responses of invertebrate communities. River Research and Applications, 21(4) : 439-453.

Keywords : urban streams • enhancement • invertebrates • recolonization • sediment.

Abstract : The effects of habitat enhancement on the invertebrate communities in five urban streams in Christchurch, New Zealand, were investigated. All streams underwent riparian planting, while extensive channel modifications were made at two streams, where a concrete dish channel and a wooden timber-lined stream were removed and natural banks reinstated. Benthic invertebrates were collected before enhancement and 5 years after from the same locations. Invertebrates were also collected from control sites in each stream in 2001. Desired goals of enhancement activities included increasing the densities of mayflies and caddisflies, and decreasing densities of oligochaetes, snails and midges. Enhancement activities changed riparian vegetation and bank conditions, as well as substrate composition, instream organic matter and variability of instream velocities. Invertebrate communities prior to enhancement were typical of those in urban environments, and dominated by snails (*Potamopyrgus*, *Physa*), the amphipod *Paracalliope*, the hydroptilid caddisfly *Oxyethira*, oligochaetes and chironomids. Stream enhancement caused only small changes to the invertebrate community, with subtle shifts in overall abundance, species evenness, diversity, and ordination scores. Lack of a consistent strong response by invertebrates to enhancement activities, and continued absence of caddisflies and mayflies from enhanced sites may reflect lack of sufficient change to instream conditions as a result of stream enhancement, colonization bottlenecks for aerial stages of these animals, and the inability of individuals outside the urban watershed to perceive these enhanced 'islands' of good habitat. Alternatively, contamination of streambed sediments, excess sedimentation and reduced base flows may be limiting factors precluding successful invertebrate colonization in enhanced sites. These results highlight the importance of setting clear goals and objectives necessary to meet these goals. Enhancement of riparian zones in urban streams may not be adequate to improve benthic invertebrate communities. Identifying over-arching factors that potentially limit invertebrate communities will enable the enhancement potential of streams to be better assessed, and allow managers to identify sites where recovery of biological communities is possible, and where such recovery is not.

- 218 - Sweka J.A. & Hartman K.J., 2006. Effects of Large Woody Debris Addition on Stream Habitat and Brook Trout Populations in Appalachian Streams. Hydrobiologia, 559(1) : 363-378.

Key words : large woody debris • brook trout •stream habitat.

Abstract : Large woody debris (LWD) was added to eight streams in the central Appalachians of West Virginia to determine if stream habitat could be enhanced and brook trout (*Salvelinus fontinalis*) populations increased. Brook trout populations were assessed one year prior to habitat manipulation and 3 years post-habitat manipulation. LWD was added by felling approximately 15 trees per 300 m stream reach. Four of the streams had LWD added to one 300 m reach with 300 m unmanipulated reaches upstream and downstream of the manipulated reach to observe within-stream effects of LWD additions on brook trout density. The remaining four streams had LWD added to three 300 m reaches and these streams were compared to those with only a single 300 m manipulated reach to observe the effects of the extent of habitat manipulation on brook trout density. New pools were formed by the addition of LWD, but overall pool area did not increase significantly in reaches where LWD was added. The relatively high gradient and coarse substrate of these streams may have precluded the added LWD from having a significant influence on stream channel morphology and habitat complexity. No pools were formed in the highest gradient stream, while the stream with the most pools formed had the lowest gradient. Brook trout populations fluctuated following habitat manipulations, and there was no overall effect of the LWD additions on within-stream variability in brook trout density. When there were significant differences among-streams with different extents of LWD additions, those streams receiving LWD additions over a large extent had the greatest brook trout densities. The full potential of added LWD to change stream habitat and influence on brook trout populations may take more time to develop than the 3 years post-manipulation period of this study.

- 219 - Talmage P.J., Perry J.A. & Goldstein R.M., 2002. Relation of Instream Habitat and Physical Conditions to Fish Communities of Agricultural Streams in the Northern Midwest. North American Journal of Fisheries Management, 22(3) : 825-833.

Abstract : Fish, instream habitat, and physical stream conditions were surveyed in 29 agricultural streams in the Red River of the North basin during summer 1994 and the Minnesota River basin during summer 1997. Our goal was to determine which instream habitat and physical conditions should be considered for stream restoration. Principle components analysis identified six axes that explained 79% of the total variability in instream habitat and physical conditions. Percent run, percent boulder, percent woody debris, percent overhanging vegetation, percent sand, and frequency of erosion were the variables best associated with these axes. Multiple linear regression analysis of the instream habitat and physical conditions explained 14–50% of the variability in fish community composition. Managers of agricultural warmwater streams in the northern Midwest should emphasize these six instream habitat and physical conditions, and the factors that influence them, during stream restoration.

- 220 - Thomas R.H. & Blakemore F.B., 2007. Elements of a cost–benefit analysis for improving salmonid spawning habitat in the River wye. Journal of Environmental Management, 82(4) : 471-480.

Keywords : cost–benefit analysis • willingness to pay • contingent valuation method • salmonid • riparian habitat • River Wye.

Abstract : Contingent valuation methods were used to derive an economic value for salmonid spawning habitat restoration. Anglers' willingness to pay for such restoration and farmers' willingness to accept compensation for lost productivity due to the restoration were investigated using questionnaire and face-to-face surveys, respectively. These elements were combined with the Wye Habitat Improvement Project (WHIP) budget into a cost–benefit analysis (CBA) based upon direct use values only. The CBA assumed that the WHIP will improve salmonid stock. Different levels of investment were considered and the CBA gave a positive net present value indicating an economically viable project and benefit-to-cost ratios greater than one for minor projects. However, the number of anglers using the Wye would need to double or triple in order to justify the full WHIP budget. Management of an environmental resource must consider users' and stakeholders' needs and

opinions. It was found that anglers on the Wye value habitat/scenery in its own right and that this played an important part in the activity. Farmers' agreement regarding involvement in such projects was more likely to be determined by their political and ethical views than receiving an economic compensation.

- 221 - Thompson D.M., 2002. Long-Term Effect of Instream Habitat-Improvement Structures on Channel Morphology Along the Blackledge and Salmon Rivers, Connecticut, USA. Environmental Management, 29(2) : 250-265.

Keywords : pool-riffle morphology • stream restoration • grade-control structure • deflector • cover structure.

Abstract : Habitat-improvement structures on the Blackledge and Salmon rivers date back to the 1930s and 1950s. Forty of these structures were investigated to determine their long-term impact on channel morphology. These structures include designs that continue to be used in modern restoration efforts. During the intervening period since these structures were introduced, several major floods have affected the two channels. The floods include three flows in excess of the 50-year event, including the flood of record, which has an estimated recurrence interval of almost 300 years. Despite the extreme flooding, many structures were discovered in varying conditions of operation. Grade-control structures and low-flow deflectors generally create some low-flow habitat ($P = 0.815$) but do not produce the depth of water predicted by design manuals ($P < 0.0001$). Unintended erosion has developed in response to many of the channel modifications especially along the outside of meanders. In addition, the mode of failure of grade-control structures has created localized channel widening with associated bank erosion. Meanwhile, cover structures have produced a 30% reduction in streamside vegetation with over 75% less overhead cover than unaltered reaches. Based on these results, it is important for prospective designers to carefully consider the long-term impacts of instream structures when developing future channel-restoration projects.

- 222 - Thompson D.M., 2005. The history of the use and effectiveness of instream structures in the United States. Reviews in Engineering Geology XVI : Humans as Geologic Agents, 35–50.

Keywords: channel restoration • stream improvement • habitat structures • fisheries management.

Abstract : The use of instream structures, devices designed to improve fish habitat, began as early as 1880 in the United States and continues today. The practice of stream improvement was partially motivated by the desire to compensate for overfishing problems. Many of the practices that involve the use of instream structures emerged during a time period when scientific-management principles offered the hope that humans could eliminate perceived inefficiencies and increase biological productivity in natural systems. Decades later, modern criteria of instream structures trace many of their details of design to experimental devices employed in the 1920s and 1930s. However, problems with the use of many styles were noted soon after they were first deployed, and many of these troubles persist today. Dams can be undermined and outflanked by flows. Deflectors disrupt the bed and hamper the development of food organisms. Finally, cover structures suffer from siltation problems and long-term decay, which renders the devices useless. The best possible long-term solution to improved health of riverine fisheries may be to avoid the use of static engineering structures when possible and focus on reforestation and erosion control in the watersheds. Even this recommendation dates back over 65 years to the period when the use of instream structures first began to flourish in the United States.

- 223 - Thompson D.M., 2006. Did The Pre-1980 Use Of In-Stream Structures Improve Streams? A Reanalysis Of Historical Data. Ecological Applications, 16(2) : 784–796.

Key words: applied geomorphology • erosion control • habitat improvement • in-stream structures • stream improvement.

Abstract : In the 1930s, after only three years of scientific investigation at the University of Michigan Institute for Fisheries Research, cheap labor and government-sponsored conservation projects spearheaded by the Civilian Conservation Corps allowed the widespread adoption of in-stream structures throughout the United States. From the 1940s through the 1970s, designs of in-stream structures remained essentially unchanged, and their use continued. Despite a large investment in the construction of in-stream structures over these four decades, very few studies were undertaken to evaluate the impacts of the structures on the channel and its aquatic populations. The studies that were undertaken to evaluate the impact of the structures were often flawed. The use of habitat structures became an “accepted practice,” however, and early evaluation studies were used as proof that the structures were beneficial to aquatic organisms. A review of the literature reveals that, despite published claims to the contrary, little evidence of the successful use of in-stream structures to improve fish populations exists prior to 1980. A total of 79 publications were checked, and 215 statistical analyses were performed. Only seven analyses provide evidence for a benefit of structures on fish populations, and five of these analyses are suspect because data were misclassified by the original authors. Many of the changes in population measures reported in early publications appear to result from changes in fishing pressure that often accompanied channel modifications. Modern evaluations of channel-restoration projects must consider the influence of fishing pressure to ensure that efforts to improve fish habitat achieve the benefits intended. My statistical results show that the traditional use of in-stream structures for channel restoration design does not ensure demonstrable benefits for fish communities, and their ability to increase fish populations should not be presumed.

- 224 - Thompson D.M. & Stull G.N., 2002. The development and historic use of habitat structures in channel restoration in the united states : the grand experiment in fisheries management. Géographie physique et Quaternaire, 56(1) : 45-60.

Abstract : The use of instream structures to modify aquatic habitat has a long history in the United States. Pioneering work by wealthy landowners in the Catskills region of New York produced a range of designs in the decades preceding the Great Depression in an effort to replenish fish populations depleted from overfishing. The scientific evaluation of structures began in 1930. Within two years, a Michigan research team claimed improved fish populations. Cheap labor and government- sponsored conservation projects spearheaded by the Civilian Conservation Corps allowed the widespread adoption of the techniques in the 1930s, before adequate testing of the long-term impact of the devices. The start of World War II temporarily ended the government conservation efforts and prevented the continued evaluation of structures. During the 1940s, 1950s and 1960s, designs of instream structures remained essentially unchanged. Meanwhile, the small number of evaluations of the impact of the structures often were flawed. The continued use of early designs of instream structures helped instill a false belief that instream structures were proven to be a benefit to fish. Even modern use of instream structures continues to rely on the basic blueprints developed in the Catskills, despite documented problems with the use of these designs.

Résumé : *Le développement et l’histoire des structures destinées à l’habitat aquatique dans les cours d’eau aux États-Unis : un essai de gestion des populations de poissons.* L’emploi de structures aménagées dans le lit des rivières visant à modifier l’habitat aquatique a une longue histoire aux États- Unis. Des travaux pionniers effectués par de riches propriétaires terriens dans la région des Catskills (État de New York) ont entraîné l’élaboration d’un éventail de designs durant les décennies qui ont précédé la Grande Dépression ; ceux-ci visaient le rétablissement des populations de poissons lourdement touchées par une pêche excessive. L’évaluation scientifique de ces structures a débuté en 1930. En moins de deux ans, une équipe de recherche du Michigan a déclaré avoir obtenu un accroissement des populations de poissons. Dans les années 1930, une main-d’oeuvre bon marché et des projets de conservation subventionnés par le gouvernement et supervisés par le *Civilian Conservation Corps* ont concouru à étendre à grande échelle l’emploi des techniques du Michigan et ce, avant même qu’une évaluation adéquate des effets à long terme de tels dispositifs ne soit

complétée. Le début de la Seconde Guerre mondiale a temporairement interrompu les efforts de conservation gouvernementaux et a empêché l'évaluation suivie des structures en place. Durant les années 1940, 1950 et 1960, le design de ce type de structures est demeuré pratiquement inchangé et les quelques recherches réalisées pour évaluer leur impact se sont souvent révélées erronées. L'usage continu de ces dispositifs primitifs a contribué à corroborer la fausse croyance selon laquelle leur effet bénéfique sur les poissons était démontré. Même maintenant, l'utilisation de ces structures aménagées dans les cours d'eau continue à reposer sur les plans rudimentaires élaborés autrefois dans les Catskills, malgré les problèmes relatés dans la littérature quant à leur emploi.

- 225 - Thorn W.C., Anderson C.S., Lorenzen W.E., Hendrickson D.L. & Wagner J.W., 1997. A Review of Trout Management in Southeast Minnesota Streams. North American Journal of Fisheries Management, 17(4) : 860-872.

Abstract : Agricultural development after 1850 in southeast Minnesota degraded instream habitat, and by 1900, the native brook trout *Salvelinus fontinalis* was extirpated from most streams. By the 1940s, after 60–70 years of stocking, the exotic brown trout *Salmo trutta* was the most common trout, but abundance was low and limited by lack of reproductive habitat. Soil conservation practices of the 1930s and 1940s and watershed management under Public Law (PL) 566 in the 1950s and 1960s reduced flooding, erosion, and sedimentation and increased infiltration and base flow. By the 1970s, brown trout reproduction was common, but abundance was still low. Fisheries managers of the Minnesota Department of Natural Resources assumed that adult habitat limited abundance, so they improved instream habitat in streams with public access, which increased brown trout abundance in some streams. Experimental management since 1975 has shown that the lack of adult habitat did limit trout abundance. This management regime has also enabled the quantification of habitat quality and has developed a decision key for brown trout management. When land management has degraded stream habitat, land treatments, acquisition of riparian corridors, and instream management are necessary to rehabilitate habitat and provide recreational fisheries.

- 226 - Tikkanen P., Laasonen P., Muotka T. Huhta A. & Kuusela K., 1994. Short-term recovery of benthos following disturbance from stream habitat rehabilitation. Hydrobiologia, 273(2) : 121-130.

Keywords : stream rehabilitation • benthic macroinvertebrates • disturbance • recovery.

Abstract : The recovery of benthic macroinvertebrates after disturbance from stream rehabilitation was studied in the River Livojoki, northern Finland. The stream that had been channelized for log transport was rehabilitated on 1 July 1992 by digging holes and inserting boulders. We measured habitat characteristics and sampled benthic animals before and after rehabilitation, including an unrehabilitated control site. The immediate effect of rehabilitation was a slight decrease in the abundances of benthic insects. Recolonization occurred rapidly, within 10 days. Disturbance of the rehabilitation did not have a detectable effect on the macroinvertebrate community. Most species-level changes and community patterns reflected seasonal life history events. Timing of such rehabilitation work can be critical for the recovery rate, which depends on the colonization abilities of the species present after disturbance. We suggest that many disturbances (including minor floods and moderate rehabilitation procedures) may have only small, short-term effects on benthic communities. We emphasize the importance of considering seasonality in studies of disturbance in streams.

- 227 - Tompkins M.R. & Kondolf G.M., 2007. Systematic Postproject Appraisals to Maximize Lessons Learned from River Restoration Projects: Case Study of Compound Channel Restoration Projects in Northern California. Restoration Ecology, 15(3) : 524–537.

Abstract : We conducted systematic postproject appraisals (PPAs) of seven compound channel restoration projects, supplementing available data with new field data and analyses to produce comparable datasets for all seven projects. We describe how systematic PPAs can be developed and illustrate a systematic PPA for compound channel projects organized around performance with respect to geomorphic, habitat, and conveyance objectives. We found that preexisting monitoring programs for a group of similar restoration projects can be supplemented with relatively low-effort data collection

and analyses to produce lessons on a "class" of restoration projects. Using this approach to assess a set of seven compound channel projects, we found that two fully achieved geomorphic objectives, three appear likely to achieve geomorphic objectives with additional time and/or minor interventions, and two did not achieve geomorphic objectives. Further, four projects achieved habitat objectives and three projects appeared likely to achieve objectives if given more time to develop and/or a minor intervention to mitigate limitations on critical ecological processes. Finally, four of the projects satisfied conveyance objectives, and the remaining three appeared likely to satisfy objectives with minor interventions to maintain design roughness and geometry conditions. Based on observations from our new systematic PPA approach applied to compound channels in Mediterranean climates, we suggest application of systematic PPAs for other classes of river restoration projects to evaluate scale and geomorphic setting issues in project design, to refine postproject monitoring guidelines, and to predict vegetation recruitment, growth, and succession patterns to avoid potential vegetation problems.

- 228 - Tullos D.D., Penrose D.L. & Jennings G.D., 2006. Development and application of a bioindicator for benthic habitat enhancement in the North Carolina Piedmont. Ecological Engineering, 27(3) : 228-241.

Keywords : benthic macroinvertebrate • habitat enhancement • indicator species • stream restoration • reference condition • bioassessment.

Abstract : This paper describes the development, application, and evaluation of a method for assessing the effectiveness of stream restoration activities in enhancing four lotic habitats based on the presence of habitat specialists. Three genera were identified as specialists for indicators of the enhancement of woody debris, coarse bed substrate, fine roots, and leaf pack habitats. These indicator genera were determined for each habitat type through indicator species analysis, extensive literature review, and consultation with local experts and a statewide distribution database. Water quality influences were isolated by excluding taxa with low tolerance to degraded water quality conditions. The difference in the presence of indicator genera between pairs of upstream-restored reaches was used to evaluate the success of the restoration activities in re-establishing benthic habitats. Application of this methodology to 27 paired reaches in the North Carolina Piedmont indicated that no change in specialists was the most frequent result of restoration, particularly for the woody debris habitats, when each habitat was examined individually. By combining the habitats into a composite score, a distinction by land use emerged, with habitats in urban areas indicating the greatest enhancement, while presence of the indicator genera at the agricultural and rural sites showed no clear trend of improvement or degradation in response to the restoration activities. When this composite IG metric was compared to the EPT taxa richness metric and RBP scores, the dependency of the EPT taxa richness metric on upstream conditions and the improvement in discriminatory ability over the RBP score suggest that this indicator genera (IG) metric provides a distinct signal for representing the biological perspective on the enhancement of benthic habitats by stream restoration activities. While further development of the methodology is desirable, this framework introduces a valuable alternative for evaluating benthic habitat enhancement in various hydrogeographic and land use conditions, and is constructive for guiding restoration designs to maximize biotic integrity.

- 229 - Van Zyll De Jong M.C., Cowx I.G. & Scruton D.A., 1997. An evaluation of instream habitat restoration techniques on salmonid populations in a Newfoundland stream. Regulated Rivers: Research & Management, 13(6) : 603-614.

Keywords : Atlantic salmon • *Salmo salar* • brook trout • *Salvelinus alpinus* • habitat • restoration • Newfoundland.

Abstract : The effect of three types of habitat improvement structures were evaluated in Joe Farrell's Brook, a small second order salmonid stream in Newfoundland, Canada which had been adversly affected by forest harvesting activities. Fish populations and key habitat attributes were monitored prior to and, in two subsequent years after, boulder clusters, V-dams and half-log covers were placed at selected sites in channellised reaches. Boulder clusters proved to be the most effective structure, increasing densities of 0+, 1+, and 3+ juvenile Atlantic salmon *(Salmo salar* L.*)* after placement of instream devices. V-dams proved to be effective in increasing both the density of brook trout

(Salvelinus fontinalis Mitchel) and Atlantic salmon through the creation of more diverse pool habitat. Half-log covers increased the number of juvenile salmon age 0+ through an increase in instream cover. These increases in salmonid abundance, however, were considered not to be solely attributed to an improvement in physical habitat. Other factors may influence or modify productivity of the stream reaches treated. For example, relative abundance, size distribution, biomass, and production are controlled by physical and chemical habitat variables and are modified through inter- and intra-specific competition. The general conclusion was that the restoration techniques increased habitat heterogenity and the degree of habitat complexity in channellised sections; therefore, reducing competition and increasing production.

- 230 - Vehanen T., Huusko A., Yrjänä T., Lahti M. & Mäki-Petäys A., 2003. Habitat preference by grayling (*Thymallus thymallus*) in an artificially modified, hydropeaking riverbed: a contribution to understand the effectiveness of habitat enhancement measures. Journal of Applied Ichthyology, 19(1) : 15–20.

Abstract : This paper describes a case study to rehabilitate habitat for adult European grayling (*Thymallus thymallus* L.) in a large river reservoir in northern Finland. A channelled river reach was restored by building small islands and reefs as well as cobble and boulder structures for grayling. The total area of the restored stretch was 1.0 ha. The physical habitat was mapped using an echosounder, Doppler device, tachometer and scuba diving, and modelled with a 2D hydraulic model. The mean water velocity in the modelled stream section was 0.28 m s^{-1} during 110 m^3 s^{-1} flow and 0.43 m s^{-1} during 300 m^3 s^{-1} flow. Twelve adult grayling, tagged with transmitters, were released into the area and tracked for a maximum period of 30 days. The grayling largely stayed in the restored area and tended to avoid the unchanged channel of the river. The range of daily movement was from stationary to 2700 m per day. The adult grayling preferred water velocities between 0.20 and 0.45 m s^{-1}, water depths between 0.20 and 1.55 m and coarse substrate. The study provides a small part of the information needed in habitat restoration for grayling.

- 231 - Verdonschot P.F.M. & Nijboer R.C., 2002. Towards a decision support system for stream restoration in the Netherlands: an overview of restoration projects and future needs. Hydrobiologia, 478(1-3) : 131-148.

Keywords : decision support system • stream restoration • key factor • inquiry • water management • lowland stream.

Abstract : Stream restoration is one of the answers to the lowland stream deterioration. For making proper choices in stream restoration; one firstly needs to understand the complex spatial and temporal interactions between physical, chemical and biological components in the stream ecosystem. Several ecological concepts on the four dimensions, scale and hierarchy in a stream ecosystem are integrated into the 5-S-model. This model provides the theoretical backbone of the first outline of a decision support system for stream restoration. Stream restoration is developing fast in the Netherlands. In 1991, 70 projects were counted, in 1993 there were 170, and this number increased in 1998 to 206. Positive signs in this increase in the number of stream restoration projects are the increase in the amount of money, in background studies, in improvement of the selection process of stretches to be tackled, and the broadening of the objectives and measures. Negative signs are amongst others that measures often deal only with stream hydrology and structures in-stream. The catchment takes no part. Furthermore, bottlenecks often relate to finances and agreement between people and/or organisations. Finally, the first steps towards a decision support system for stream restoration are made. The system presented provides only information based on which measures should be taken. `Where and how' these measures need to be taken remains a challenge for the future.

- 232 - Walsh C.J., Fletcher T.D. & Ladson A.R., 2005. Stream restoration in urban catchments through redesigning stormwater systems: looking to the catchment to save the stream. Journal of the North American Benthological Society, 24(3) : 690–705.

Keywords: ecological restoration • urban • watershed • stormwater • impervious area • drainage connection • low-impact design • water-sensitive urban design • retrofit.

Abstract : Restoration of streams degraded by urbanization has usually been attempted by enhancement of instream habitat or riparian zones. Such restoration approaches are unlikely to substantially improve instream ecological condition because they do not match the scale of the degrading process. Recent studies of urban impacts on streams in Melbourne, Australia, on water chemistry, algal biomass and assemblage composition of diatoms and invertebrates, suggested that the primary degrading process to streams in many urban areas is effective imperviousness (EI), the proportion of a catchment covered by impervious surfaces directly connected to the stream by stormwater drainage pipes. The direct connection of impervious surfaces to streams means that even small rainfall events can produce sufficient surface runoff to cause frequent disturbance through regular delivery of water and pollutants; where impervious surfaces are not directly connected to streams, small rainfall events are intercepted and infiltrated. We, therefore, identified use of alternative drainage methods, which maintain a near-natural frequency of surface runoff from the catchment, as the best approach to stream restoration in urban catchments and then used models of relationships between 14 ecological indicators and EI to determine restoration objectives. Ecological condition, as indicated by concentrations of water-quality variables, algal biomass, and several measures of diatom and macroinvertebrate assemblage composition, declined with increasing EI until a threshold was reached (EI = 0.01–0.14), beyond which no further degradation was observed. We showed, in a sample catchment, that it is possible to redesign the drainage system to reduce EI to a level at which the models predict detectable improvement in most ecological indicators. Distributed, low-impact design measures are required that intercept rainfall from small events and then facilitate its infiltration, evaporation, transpiration, or storage for later in-house use.

- 233 - Wang L., Simonson T.D. & Lyons J., 1996. Accuracy and Precision of Selected Stream Habitat Estimates. North American Journal of Fisheries Management, 16 : 340–347.

Abstract : The precision and accuracy of estimates of stream habitat variables were evaluated in three southern Wisconsin streams. Among-observer precision was estimated from six observers with three different levels of experience. The precision of estimates for 27 stream habitat variables was generally good; 46% of the confidence intervals of the overall means for six observers were less than or equal to the field measurement precision. Stream width and water depth were estimated most precisely; these were followed by substrate composition, cover for fish, and bank susceptibility to erosion. Estimates of bank vegetation or land use and gravel embeddedness were the least precise. We determined accuracy of quantifying substrate composition by comparing direct visual observations from the same six observers with values obtained from digitized photographs of the same area of substrate. The results showed that 73% of the differences between visually estimated substrate values and digitized values were less than 5 percentage points, and none were greater than 12 percentage points. Accuracy and precision were lowest in the streams with the most heterogeneous habitat. Overall, our results indicate that visual estimates of substrate composition are sufficiently accurate for many fisheries applications. No significant differences in accuracy were found for estimates of substrate compositions obtained by the least and the most experienced observers. Variation among trained observers was relatively low for most habitat variables but fairly high for bank vegetation or land use and for gravel embeddedness. If initial training is adequate, experience of observers has little effect on the accuracy and precision of estimates.

- 234 - Ward J.V., Tockner K., Uehlinger U., & Malard F., 2001. Understanding natural patterns and processes in river corridors as the basis for effective river restoration. Regulated Rivers: Research & Management, 17(4-5) : 311-323.

Keywords : connectivity • disturbance • floodplains • landscape ecology • river corridors • river restoration • succession.

Abstract : Running water ecology is a young science, the conceptual foundations of which were derived largely from research conducted in Europe and North America. However, virtually all European river corridors were substantially regulated well before the science of river ecology developed. While regulation of North American river systems occurred later than in European systems, river ecology also developed later. Therefore, there is a general impression of rivers as being much less heterogeneous and much more stable than they actually are in the natural state. The thesis of this paper is that established research and management concepts may fail to fully recognize the crucial roles of habitat heterogeneity and fluvial dynamics owing to a lack of fundamental knowledge of the structural and functional features of morphologically intact river corridors. Until quite recently, most concepts in river ecology were based on the implicit assumption that rivers are stable, single-thread channels isolated from adjacent floodplains. Unfortunately, many rivers are in just such a state, but it should be recognized that this is not the natural condition. This incomplete understanding constrains scientific advances in river ecology and renders management and restoration initiatives less effective. Examples are given of the high level of spatio-temporal heterogeneity that may be attained in rivers where natural processes still operate on a large scale. The objective of this paper is to promulgate a broader and more integrative understanding of natural processes in river corridors as a necessary prelude to effective river conservation and management.

- 235 - Warner K. & Porter I.R., 1960. Experimental Improvement of a Bulldozed Trout Stream in Northern Maine. Transactions of the American Fisheries Society, 89(1) : 59-63.

Abstract : Brook-trout habitat in Big Hudson Brook was destroyed in 1950 by extensive bulldozing in preparation for pulpwood driving. Following bulldozing, the brook had no well-defined channel at low water levels, water temperatures reached the mid-seventies, and the small flow seeped through bottom rubble. Although restoration of original habitat conditions was impossible, an attempt was made, using a bulldozer, to improve trout-stream habitat that had been destroyed earlier by bulldozing. Seventy-one wing deflectors, 10 rock dams, and 6 spring holes were created by a single bulldozer in 3 working days. Evaluation of the work 2 years later showed that 63 deflectors had successfully narrowed stream flow or created pools, rock dams were largely unsuccessful, and pools created by excavation of spring areas commonly harbored trout during warm summer weather.

- 236 - Weber C., Peter A & Zanini F., 2007. Spatio-temporal analysis of fish and their habitat: a case study on a highly degraded Swiss river system prior to extensive rehabilitation. Aquatic Sciences - Research Across Boundaries, 69(1) : 162-172.

Keywords : catchment • hydropeaking • rehabilitation • brown trout • historical analysis • river Rhone.

Abstract : The failure of river rehabilitation projects is often reported in the literature. One possible reason for this failure is the insufficient consideration of factors degrading riverine ecosystems at large spatio-temporal scales. A precedent analysis of the evolution and significance of these factors at the watershed level is proposed as a prerequisite for a successful rehabilitation project. Based on a watershed-scale approach, we investigated the current and historical states of the fish assemblage and of relevant abiotic factors in the river Rhone, a seventh-order stream in Switzerland scheduled for large-scale rehabilitation. Recent field data gathered by electrofishing and habitat mapping were analysed by means of a mixed model approach and were qualitatively compared compared to historical information derived from topographic maps and documentary sources.
The length of the entire active channel has been reduced by 45% (102 km) since 1850, representing a significant diminution in lateral connectivity. Our recent fish survey revealed a depleted species set, with only two of 19 historically documented species found. The density of brown trout was generally low, but positively correlated with the presence of cover. Thus, morphological improvements, e.g.

through local river widening, offer extensive potential for the restoration of native fish assemblages, but will probably only be successful in combination with a more natural hydrological regime.

- 237 - Wheaton J.M., Darby S.E., Sear D.A. & Milne J.A., 2006. Does scientific conjecture accurately describe restoration practice? Insight from an international river restoration survey. Area 38(2) : 128–142.

Abstract : Few sources exist to draw generalizations about the incredibly diverse international river restoration community. Generalizations in the restoration literature tend to be grounded on individual experiences or logical conjecture. To fill this perceived gap, an international web-based survey was launched. Over 500 respondents from 37 different countries participated. The results, posted on the web, act as a database of perceptions and individual experiences, from which the restoration community can make their own interpretations. With three examples, we contrast scientific conjecture with the perceptions of the restoration community who participated in this survey.

- 238 - Woodsmith R.D., Noel J.R. & Dilger M.L., 2005. An approach to effectiveness monitoring of floodplain channel aquatic habitat: channel condition assessment. Landscape and Urban Planning, 72(1-3) : 177-204.

Keywords : channel condition • aquatic habitat • effectiveness monitoring.

Abstract : The condition of aquatic habitat and the health of species dependent on that habitat are issues of significant concern to land management agencies, other organizations, and the public at large in southeastern Alaska, as well as along much of the Pacific coastal region of North America. We develop and test a set of effectiveness monitoring procedures for measuring change in floodplain channel habitat in southeastern Alaska. Variables include measures of channel morphology, pool size, pool spatial density, and bed surface grain size distribution. These procedures provide methods of data collection and analysis that, in the context of a statistically defensible sampling protocol, allow for determination of rate and direction of change among different intensities of land use, and thereby evaluation of management strategies. Assessment of channel condition can also contribute to evaluation of both restoration needs and success of restoration activities. Information gained from these procedures, together with information, where available, on watershed and riparian condition and processes and land use history will contribute to interpretation of measured change and its linkage to specific disturbances. Relationships among channel condition indicators and salmonid densities as well as opportunities for future research to better understand ecosystem elements that support biologic productivity are addressed in a companion paper in this volume (Bryant and Edwards).

- 239 - Woolsey S., Capelli F., Gonser T., Hoehn A., Hostmann M., Junker B., Paetzold A., Roulier C., Schweizer S. Tiegs S.D., Tockner K., Weber C. & Peter A., 2007. A strategy to assess river restoration success. Freshwater Biology, 52(4) : 752-769.

Abstract :

1- Elaborate restoration attempts are underway worldwide to return human-impacted rivers to more natural conditions. Assessing the outcome of river restoration projects is vital for adaptive management, evaluating project efficiency, optimising future programmes and gaining public acceptance. An important reason why assessment is often omitted is lack of appropriate guidelines.

2- Here we present guidelines for assessing river restoration success. They are based on a total of 49 indicators and 13 specific objectives elaborated for the restoration of low- to mid-order rivers in Switzerland. Most of these objectives relate to ecological attributes of rivers, but socio-economic aspects are also considered.

3- A strategy is proposed according to which a set of indicators is selected from the total of 49 indicators to ensure that indicators match restoration objectives and measures, and that the required effort for survey and analysis of indicators is appropriate to the project budget.

4- Indicator values are determined according to methods described in detailed method sheets. Restoration success is evaluated by comparing indicator values before and after restoration

measures have been undertaken. To this end, values are first standardised on a dimensionless scale ranging from 0 to 1, then averaged across different indicators for a given project objective, and finally assigned to one of five overall success categories.

5- To illustrate the application of this scheme, a case study on the Thur River, Switzerland, is presented. Seven indicators were selected to meet a total of five project objectives. The project was successful in achieving 'provision of high recreational value', 'lateral connectivity' and 'vertical connectivity' but failed to meet the objectives 'morphological and hydraulic variability' and 'near natural abundance and diversity of fauna'. Results from this assessment allowed us to identify potential deficits and gaps in the restoration project. To gain information on the sensitivity of the assessment scheme would require a set of complementary indicators for each restoration objective.

- 240 - Young T.P., 2000. Restoration ecology and conservation biology. Biological Conservation, 92 : 73-83.

Abstract : Restoration ecology is undergoing rapid growth as an academic discipline, similar to that experienced by conservation biology over the last 15 years. Restoration ecology and conservation biology share many underlying biodiversity goals, but differ in striking ways. Using data from published literature in these two fields, I document that conservation biology has been more zoological, more descriptive and theoretical, and more focused on population and genetic studies than restoration ecology, which has been more botanical, more experimental, and more focused on population, community and ecosystem studies. I also use documented trends in population, land use, and biodiversity awareness to suggest that in the future ecological restoration will play an increasing role in biodiversity conservation. The conservation mind set is one of loss on a relatively short time horizon, whereas the restoration mind set is one of long-term recovery. I suggest that a restoration mind set can provide useful insights into problems of conservation today, illustrated with examples examining edge effects and integrated conservation and development projects.

- 241 - Zedler J.B., 2007. Success: An Unclear, Subjective Descriptor of Restoration Outcomes. Ecological Restoration, 25(3):162-168.

Keywords : clarity • failure • objectivity • restoration science • scientific communication • success.

Abstract : The continuing development of the science of restoration is muddled by unclear and inconsistent use of the term "success." In recent issues of two journals, *Restoration Ecology* and *Ecological Engineering,* 116 papers employed the term to predict outcomes, judge outcomes, describe criteria for judging projects, or refer to an ecosystem attribute, all in the restoration context. Only ten papers used "failure." In this article I argue that ecologists can communicate with greater clarity and objectivity by omitting or clarifying the word success when publishing in the scientific literature. Many uses can easily be dropped (for example, compliance success can become compliance, and establishment success can be establishment). A common term, "restoration success" would be clearer if replaced with more specific terms (for example, project completion, achieving dense plant cover, supporting high species richness, or colonization by target species). At minimum, authors can define the term and use it consistently. When meant as a value judgment, it would help to say, "*In my opinion*, the project was a success" (or failure) and then specify on what basis the judgment was made. Thus, I recommend abstinence, substitution, and clarification of the term success to aid communication and help restoration ecology mature as a science.

- 242 - Zeh M. & Dönni W., 1994. Restoration of spawning grounds for trout and grayling in the river High-Rhine. Aquatic Sciences - Research Across Boundaries, 56(1) : 59-69.

Keywords : Rhine • siltation • clogging • habitat restoration • salmonids • equilibrium diffusion technique • porewater samplers.

Abstract : In January 1990 10 m^3 of washed gravel (grain size 16–50 mm) were introduced in an impounded section of the River High-Rhine to test its potential as a spawning ground for salmonids. The process of infiltration of fine sediments into the gravel and subsequent clogging was monitored for three years. Levels of clogging of the gravel matrix were estimated and ranged from slight to moderately-heavy. The degree of clogging was lower in winter than in summer. Since no bedload transport was observed during the study period, flood events could wash out sediments from the top layer of the gravel bed only. An equilibrium diffusion technique using porewater samplers was employed to measure oxygen concentrations within the interstitial space during the spawning period of*Thymallus thymallus* (April),*Salmo trutta fario* and*Oncorhynchus mykiss* (December till February). Oxygen concentration decreased with increasing depth and during the course of the study period. Oxygen concentrations measured as a reference in the interstitial of the confluence of the river Glatt were considerably lower than those of the new gravel bed. A wide range of O_2 concentrations was found in winter 1991/92 and in spring 1992. This could be explained by the heterogeneous microstructure of the substrate. Successful embryonic and larval development of grayling in the gravel bed was observed in spring 1991 and 1992. However, no eggs or larvae of brown trout or rainbow trout were found. Habitat restoration projects for salmonids in impoundments of the High-Rhine are critically discussed.

- 243 - Zika U. & Peter A., 2002. The introduction of woody debris into a channelized stream: effect on trout populations and habitat. River Research and Applications, 18(4) : 355-366.

Keywords : large woody debris • brown trout • *Salmo trutta* • rainbow trout • *Oncorhynchus mykiss* • cover habitat.

Abstract : Large woody debris was explored as a method of restructuring channelized streams to improve salmonid habitat. Whole trees were inserted in sections along a 2 km reach of a channelized stream to determine if large woody debris: (1) increased the abundance and biomass of brown (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*); (2) had an effect on physical habitat features; and (3) provided trouts with additional habitat. Trout populations and stream morphology were monitored before and after the introduction of woody debris and compared to control sections lacking woody debris. Abundance and biomass of both brown and rainbow trout increased in the treatment section compared to the control. Maximum and standard deviation of fish total length increased in all sections during summer months. The number of individuals and the standard deviations of total lengths decreased in the control section in winter, but increased in the treatment section. Mean water velocities decreased and number and volume of pools increased in treatment sections. Brown and rainbow trouts sought woody debris structures for cover. We conclude that large woody debris can serve as a method of reconstructing channelized streams to improve salmonid habitat.

Publications issues de livres

- 244 - Bates D.J., McBain G.G. & Newbury R.W., 1997. Restoration of a channelized salmonid stream, Oullette Creek, British Columbia. Sea-run cutthroat trout biology, management, and future conservation. American Fisheries Society, Oregon chapter, Corvallis, Oregon (USA), 178.

Abstract : Oullette Creek, a second-order coastal stream, is located on the Sechelt Peninsula approximately 20 kilometers from Vancouver, British Columbia. This stream, which once supported thriving populations of anadromous salmonids, was relocated and channelized in 1978. This action resulted in major changes in stream geometry that affected fish habitat. In 1993 and 1994, detailed biophysical inventories were conducted on the lower reach of Oullette Creek. These inventories were followed by redesign and restoration of fish habitat. The primary goal of the restoration was to restore the natural pool and riffle ratio with instream rock weirs built to duplicate natural riffles and pools. The result has been the collection of spawning gravel on the upstream edge of riffles and increased areas in pools for rearing. The natural geometry of a stream of this size in this region was used to set the design width, depth, substrate size, and final pool/riffle sequencing. Basic stream characteristics of bankfull width, depth, and discharge were established by surveying a series of reaches in different tributaries in the project stream and similar drainage basins located nearby. In 1995, after the first phase of the restoration was completed, a third biophysical inventory was conducted on Oullette Creek. Preliminary results indicate that the restored areas are stabilizing, providing a significant increase in rearing habitat for both coho salmon and cutthroat trout.

- 245 - Frissell C.A. & Ralph S.C., 1998. Stream and Watershed restoration. 599-624 *In* Naiman R.J. & Bilby R.E., *River ecology and management : Lessons from the Pacific coastal ecoregion. Ed. Springer, 705p*.

Overview :

- Restoration is the process of returning a river or watershed to a condition that relaxes human constraints on the development of natural patterns of diversity. Restoration does not create a single, stable state but enables the system to express a range of conditions dictated by the biological and physical characteristics of the watershed and its natural disturbance regime.
- Most restoration efforts to date have focused on the alteration of physical habitat characteristics at small spatial scales, most often the placement of logs, rocks, or wire gabions in a channel to create pools or collect gravel. The effect of such efforts on the production and survival of the target fish species is uncertain.
- Relatively few projects have attempted restoration at the reach scale. However, this approach may be well suited for severely degraded stream reaches, although accurate documentation of the effectiveness of the approach is not available.
- Restoration of an entire watershed is very rarely attempted. However, addressing restoration from this broad spatial perspective is often necessary to relax human constraints on system function. A well-designed and evaluated watershed restoration project conducted in Redwood National Park illustrates the potential effectiveness of a comprehensive approach.
- Restoration efforts are constrained by a lack of a clear understanding of how human activities have altered the processes at work within a watershed. In large part, this deficiency is the result of the failure to include monitoring as an integral part of restoration projects. Evaluation and monitoring may pay large dividends in terms of developing a full understanding of which approaches to restoration work and which do not. Monitoring also may enable the identification of small adjustments in a program that greatly increase effectiveness or reduce costs.

- 246 - Ralph S.C. & Poole G.C., 2003. 9. Putting Monitoring First: Designing Accountable Ecosystem Restoration and Management Plans. 222-242*. in* Montgomery D., Restoration of Puget Sound River, university of Washington press, 505p.

Abstract : Recovery of Puget Sound rivers and their native fish fauna will depend upon carefully documenting the ultimate effectiveness of restoration actions. Yet, as currently designed and implemented, monitoring programs are predestined to fail in this task. Consequently, our attempts to implement iterative, adaptive restoration or management actions will also fail unless managers and researchers :(1) alter their current conceptual models about the relationship between monitoring and management/restoration; (2) design and implement monitoring programs before planning restoration/management actions; (3) recognize the need for hierarchical monitoring programs and learn how to implement them; and (4) eliminate myths about monitoring, including the assumption that we can generate reliable new information about management and restoration actions simply by observing their outcomes. In order for monitoring programs to provide reliable and timely information required by iterative and adaptive approaches to ecosystem restoration and management, monitoring programs must serve as a scientifically rigorous framework for "Empirical Management" of natural resources. To accomplish this, managers and researchers must work together first to design hierarchically-structured monitoring experiments and then to plan on-the-ground management and restoration actions that serve as experimental manipulations in the context of the monitoring experiment. Unlike current approaches, this empirical approach has the potential to generate rigorous new scientific information about the efficacy of implemented actions and therefore could support adaptive, iterative improvement in management and restoration plans.

- 247 - Reeves G.H., Hall J.D., Roelofs T.D., Hickman T.L. & Baker C.O., 1991. Rehabilitating and Modifying Stream Habitats *In Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. pp. 519-557. American Fisheries Society Special Publication, no. 19.*

Abstract : Techniques for rehabilitating and modifying habitats have been used for over 50 years in fishery management, but they have been applied to a relatively small degree in the management of western North American salmonids, particularly anadromous stocks. Increased rates of harvest and other threats to the survival of many wild populations of salmon and trout call for intensified fishery management. Intensified logging, grazing, irrigation, agriculture, and urbanization have diminished the quality and quantity of habitats available to wild salmonid stocks. In principle, rehabilitation and modification of habitats are attractive means to restore the abundance of these salmonids. A recently renewed interest in habitat management has been accompanied by several review articles, symposia, and bibliographies (e.g., Parkinson and Slaney 1975; Maughan et al. 1978; Canada Department of Fisheries and Oceans and B.C. Ministry of the Environment 1980; Hassler 1981, 1984; Hall and Baker 1982; Reeves and Roelofs 1982; Gore 1985; Platts and Rinne 1985; Wesche 1985; Miller et al. 1986; Duff et al. 1988). In this chapter we focus more directly on anadromous fish habitats in the forested regions of western North America, but we have also included techniques used for resident and anadromous salmonids in streams throughout the continent. We present a general review and evaluation of past efforts in habitat management, both successful and unsuccessful. We also review current practices in western North America, outline successful techniques, and include specific recommendations on implementation. One purpose of this review is to make practical information available to field managers wishing to rehabilitate damaged habitats or to enhance habitats that are naturally low in productive capacity.

Publications parues dans actes de colloque, congrès…

- 248 - Beschta R.l., Platts W.S., Kauffman J.B. & Hill M.T., 1994. Artificial stream restoration-money well spent or exensive failure? *In proceedings, Environmental restoration, UCOWR 1994 Annual meeting Big Sky, MT., August 2-5,* pp 76-104. Carbondale, IA, University Council on Water Resources, University of Illinois.

Abstract : In this paper, we discuss the historic and present status of stream restoration in the western United States. Most of these projects were undertaken with the express purpose of improving or enhancing fisheries habitat. Case histories with a sufficient data base or study intensity to develop a better understanding of their effects are reviewed although detailed statistical evacuations are not included. Our objective is to provide improved insights to project decision makers for reevaluating whether expenditures have achieved desired results.

- 249 - Clarke K.D. & Scruton D.A., 2002. Evaluating efforts to increase salmonid productive capacity through habitat enhancement in the low diversity/production systems of Newfoundland, Canada. *In* O'Grady, ed. *Proceedings of the 13th International Salmonid Habitat Enhancement Workshop, Westport, County Mayo, Ireland, September 2002,* pp. 160-182. Dublin, Ireland, Central Fisheries Board. 267p.
(http://www.cfb.ie/salmonid_workshop/keith_clarke.htm)

Abstract : Habitat enhancement through the improvement of natural habitat and the restoration of degraded habitats has formed a significant component of salmonid management strategies in Newfoundland, Canada over the past 15 years. Projects have taken many forms with most being conducted on a small scale through local non-government organisations, mostly utilising methodologies developed in other jurisdictions, and with limited scientific evaluation. A small proportion of these projects have been conducted in conjunction with habitat researchers at the Canadian Department of Fisheries and Oceans. This sub-sample of projects, as well as directed research studies, and a few major restoration initiatives, form a substantial body of knowledge on habitat manipulations for our geographical area. These projects are reviewed under three broad categories: 1) Projects using instream structures for habitat enhancement in degraded streams; 2) Habitat improvement initiatives in natural systems, including targeted habitat manipulations and chemical additions; and 3) Major restoration or compensation projects conducted to offset habitat loses due to anthropogenic development. Each habitat enhancement methodology is discussed with respect to it's ability to increase the productive capacity of salmonid habitat under the low production conditions of Newfoundland systems.

- 250 - Down P., 2000. Geomorphological evaluation of river restoration schemes : principles, method, monitoring, assessement, evaluation. Progress? *In. River restoration in Europe : practical approches. Proceedings, conference on river restoration Wageningen, The Netherlend 2000.* 243-249.

Abstract : At present, river restoration projects are mostly experiments. Irrespective of the care taken in planning the projects, in producing suitable baseline assessments and in designing appropriate installations, the environmental benefit of individual restoration schemes cannot be predicted fully. This is often because the geomorphological impact of the scheme is dependent on a sequence of weather events after installation. Therefore, it is imperative that the environmental outcomes of restoration schemes are communicated widely and according to a rational framework that facilitates interscheme comparisons. The basis for this evaluation is Post-Project Appraisal (PPA), the final, but often overlooked, component of Environmental Assessment. PPA is argued to consist of three assessments: a compliance audit of installation accordance with design intentions, a performance audit of the short-term tendency of key geomorphological variables that indicate the probable 'sustainability' of the scheme, and a longer-term geomorphological evaluation of the physical environmental benefits of the scheme. The paper outlines three investigations into 'good practice' PPA and provides some preliminary indication of whether river restoration in the UK is providing sustainable environmental benefits.

- 251 - Doze J.H., Kamps-Mulder M.A.A.J., Kerkum F.C.M., Oosterbaan J. & van Bommel H.G., 2004. River restoration what does it mean: the restoration of the ecosystem and/or the restoration of dynamics (Monitoring the embankments of the river Hollandsche IJssel). 3rd European Conference on River Restoration, 131-137.

Keywords : ecosystem • restoration • dynamics • monitoring • ecological quality.

Abstract : The Hollandsche IJssel is a severely polluted tidal river in the southwest of the Netherlands, between the cities of Rotterdam and Gouda. Due to its canal-like character, the river does not have any dynamic tidal zones, for which reason the relevant authorities want to focus on a cleaner and a more scenic Hollandsche IJssel. To achieve these objectives, the polluted sediment will be cleaned up and the river restored to its original values. However, the ultimate effects of such interventions are not yet known. The RIZA (Institute for Inland Water Management and Waste Water Treatment) has set up a seven-year monitoring programme to gain an understanding of these effects. The monitoring centres on ecological, ecotoxicological and morphological aspects. The innovative set-up of this programme should make it possible to use the research results for the restoration of other riverbank areas. The monitoring checks unwelcome developments so that new management measures can be put forward or designed. After five years of monitoring, the first results have become known: insight into the decontamination and restoration, for example. In general, the ecological quality has improved since the intervention. The ecological risks ("ongoing poisoning") and the effects of pollution on the aquatic system have decreased or even disappeared.

- 252 - Hicks B.J. & Reeves G.H., 1994. Restoration of stream habitat for fish using in-stream structures. *Selected papers from the second day of the New Zealand Limnological Society 1993 Annual Conference, Pages 67-91 in Collier, K.J. (Ed).*

Abstract : Restoration of fish habitat by manipulating channel morphology is a common practice in western North America. Widespread damage to streams has been caused by logging, by erosion from destabilised land, by direct removal of wood from the streams, and by the use of stream channels for log transport. Most restoration techniques focus on providing pool habitat and low velocity refuges through placement of large wood or boulders in the low flow stream channel. In many instances, placement of structures has not been particularly well planned, or its effect on fish numbers evaluated. Effort has been wasted in placement of inappropriate structures, and because structures have been built without consideration of the interaction of species habitat requirements within a given stream gradient or hydrologic regime. Successful habitat restoration must take into account the limits imposed by natural stream width and gradient, beyond which enhancement cannot hope to improve, and the known habitat requirements of the species to be enhanced. The habitat requirements of many native freshwater fish species in New Zealand are insufficiently understood to permit habitat restoration with guaranteed success. In addition, restoration of rearing habitat may be of little value in the case of migratory species, for which the real limitation could be survival at sea or at some point downstream in the migratory route that may limit access. The best options to restore or protect in-stream habitat are 1) re-establishment of natural processes that provide structure to stream channels, e.g., planting woody vegetation in the margins, and 2) prevention of disturbance to riparian zones with existing woody vegetation.

- 253 - Huusko A., Vehanen T., Mäki-Petäys A. & Kotamaa J., 2005. Not just the structure: leaf (CPOM) retention as a simple, streamfunction-oriented method for assessing headwater stream mesohabitats and their restoration success. COST 626 : European Aquatic Modelling Network, Proceedings from the final meeting in Silkeborg, Denmark 19-20 May 2005, 147-150.

Abstract : Traditionally, when assessing stream habitats the focus has been placed on structural endpoints, such as flow and depth fields, or species diversity and other community attributes. The evaluation of ecosystem processes, i.e. functional endpoints, has got less attention. Here we forwarded a hypothesis whether the leaf retention could be used as a simple, streamfunction- oriented method for assessing mesohabitat quality and restoration success. The biotic communities of streams in temperate zone forested areas are highly dependent on organic material, such as the leaf fall from the riparian trees in autumn. Consequently, a high retentive capacity of a stream could indicate

beneficial conditions for benthic organisms, which in turn would propagate up in stream food webs. Our experimental results verified the view that complex stream bed structure indicates high leaf retention, and vice versa. Considering the elemental importance of leaf litter to forest streams the retention rate seems to be a good candidate for a simple stream-function-oriented tool for assessing the success of rehabilitation of streams with reduced bed heterogeneity.

- 254 - Gargan P.G, O'Grady M.F, Delanty K., Igoe, F. & Byrne C., 2002. The Effectiveness of Habitat Enhancement on Salmon and Trout Stocks in Streams in the Corrib Catchment. *In* O'Grady, ed. *Proceedings of the 13th International Salmonid Habitat Enhancement Workshop, Westport, County Mayo, Ireland, September 2002,* pp. 220-223. Dublin, Ireland, Central Fisheries Board. 267p. (http://www.cfb.ie/salmonid_workshop/paddy_gargan.htm)

Abstract : As part of the Tourism Angling Measure Programme (TAM), considerable investment was made in carrying out habitat enhancement on brown trout (*Salmo trutta* L.) and Atlantic salmon (*Salmo salar* L.) spawning and nursery streams in the Lough Corrib Catchment, Western Ireland. The programme spanned the period 1995 – 1999 and was designed to improve the angling product for both species. A range of techniques were employed to repair damaged habitat, caused primarily by either sheep overgrazing or the physical alteration of channels by arterial drainage. Works included timber or rock bank revetments, inputting of weirs, rubble mats, lateral scour pools etc. In order to measure the success of the habitat enhancement programme on juvenile salmonid production, a number of control and experimental channel sections were selected and monitored over a five year period. The effectiveness of the habitat enhancement programme on juvenile trout and salmon stocks from a range of differing channel types is examined over the period.

- 255 - Glen D.I., 2002. Recovery of Salmon and Trout Following Habitat Enhancement Works : Review of Case Studies 1995 – 2002. *In* O'Grady, ed. *Proceedings of the 13th International Salmonid Habitat Enhancement Workshop, Westport, County Mayo, Ireland, September 2002,* pp. 93-112. Dublin, Ireland, Central Fisheries Board. 267p. (http://www.cfb.ie/salmonid_workshop/duncan_glen.htm).

Abstract : The River Tweed in Scotland is internationally renowned for its Atlantic Salmon fishery which provides an income of 12.5 million pounds per annum to the economy of the Scottish Borders region and supports 520 full time equivalent jobs. The Brown trout fishery is also an important local resource.

The Tweed Foundation was formed in 1983 to undertake scientific research and management throughout the 2000 square mile Tweed catchment and our current Habitat Enhancement Project is aimed at increasing the natural productivity of Salmon, Sea trout and Brown trout within the system.

In common with most rivers in the UK, the Tweed and its tributaries have been utilised for centuries for agricultural and industrial purposes, often with detrimental effects on the fish populations.

Adult fish access to many miles of excellent quality spawning and nursery areas has been denied by a variety of man-made obstructions such as weirs, dams, culverts, bridge aprons, water intakes, fords and gravel traps.

In conjunction with the obstruction of spawning fish, many of the nursery headwaters have been severely impacted by overgrazing with farm livestock leading to a lack of instream structure and bankside vegetation.

Since 1995, the Habitat Enhancement Project has addressed these issues through a variety of practical measures including the removal and easement of obstacles, bankside fencing and implementation of instream works to restore stream structure.

This paper will present various case studies looking at the recovery of Salmon and Trout populations following habitat enhancement works including a review of techniques employed, pre and post work electric fishing data and, where appropriate, cost benefit analyses which will illustrate the importance and success of habitat enhancement from both and ecological and economic standpoint.

- 256 - Wheaton J.M., Pasternack G.B. & Merz J.E., 2004. Use of habitat heterogeneity in salmonid spawning habitat rehabilitation design. Fifth International Symposium on Ecohydraulics. Aquatic Habitats: Analysis & Restoration. Madrid, 2004, 4p.

Abstract : A shortage of salmonid spawning habitat on dammed and regulated rivers has led to the popularity of spawning habitat rehabilitation projects. Habitat heterogeneity is thought to be an important feature of aquatic ecosystems, but specific metrics for design and assessment are lacking. In August 2002, ~ 2,786 metric tons of spawning gravels and 7 large boulders were placed in a 155 meter reach on the lower Mokelumne River, California, USA. Habitat heterogeneity was incorporated into the design as part of a spawning habitat integrated rehabilitation approach (SHIRA) developed by the authors. A mix of conceptual and numerical models (2D hydrodynamic with habitat suitability and sediment entrainment submodels) were used to test the effectiveness of design scenarios. Although optimal spawning habitat as defined by habitat suitability models is generally found in riffles, proximity of habitat to structural cover (pools, large woody debris, boulder clusters and overhanging vegetation) and hydrodynamic shear zones provide equally important refuge from predation and resting zones for energy conservation. The increased heterogeneity appeared highly effe ctive in terms of redd utilization with 70 redds located in close proximity to 93% of the available structural cover, and 42 redds located in close proximity to 90% of the available shear zone refugia. Partial results emphasizing habitat heterogeneity availability and utilization metrics are presented to illustrate their potential in rehabilitation design and assessment.

- 257 - White R.J., 2002. Restoring Streams for Salmonids Where Have We Been? Where Are We Going? *In* O'Grady, ed. *Proceedings of the 13th International Salmonid Habitat Enhancement Workshop, Westport, County Mayo, Ireland, September 2002,* pp. 1-31. Dublin, Ireland, Central Fisheries Board. 267p. (http://www.cfb.ie/salmonid_workshop/ray_white.htm).

Abstract : Science-based restoration of stream habitat for salmonids is a recent endeavor. Biologists probably first guided manipulation of stream habitat to benefit salmonids in a few North American areas and only 70 years ago. Predating that were private river-keepers in the British Isles and a few interested anglers in America. State fishery agencies in the U.S. expanded "stream improvement" after World War II as concepts of habitat and ecology crept into public awareness and more field biologists were educated and hired. Measuring fish population responses began in the 1950s, and a wealth of knowledge has developed about what works and what doesn't. Certain principles apply to all stream systems, but in various respects, what works under one region's or one stream's conditions may fail elsewhere or for other species. Increased monitoring and evaluation is needed, but the high cost of doing this properly means that far from every project can be covered.

In the early years, we emphasized artificial creation of habitat—the "build-it-and-they-will-come" approach. Where done right it was very effective, at least for a few decades, but various methods prevented natural stream functioning—or fell victim to it. Maintenance and repair constitute a major problem in structural methods. Increasingly, we see the value of more natural approaches employing the *self-regenerative*, *self-sustaining* capacities of streams. We continue to learn much. New ecological insights and methods are rapidly developing, particularly in North America's Pacific-slope streams, stimulated by that region's anadromous salmonid crisis, a result of past neglect and mismanagement. When knowledge is not passed on to new personnel, institutions also forget much, reinventing methods and repeating mistakes we once learned to avoid.

The old concepts, fish management and habitat management, misled us. The essential approach is not to directly manipulate fish or habitat but to make human activity less destructive. Where a stream now lacks the wild salmonid habitat it once had, the reason is usually that human activities destroyed it. When, instead of tackling that issue by mending our ways, we try to patch up habitat with "fixes," we tend to fail in the long run. True healing—restoring a damaged stream's health to the point that wild stocks can thrive—boils down to reforming human use of land and water (and controlling fishing). Lightening our tread on the landscape, especially pulling our activities back far enough from the water's edge to let riparian zones function, can put streams in position to largely restore themselves. Water flow interacting with soils and with riparian plants and animals formed proper salmonid habitat in the first place and, given the chance, will do so again.

Rapports techniques et scientifiques:

- 258 - Archer, Eric K.; Roper, Brett B.; Henderson, Richard C.; Bouwes, Nick; Mellison, S. Chad; Kershner, Jeffrey L. 2004. Testing common stream sampling methods for broad-scale, long-term monitoring. Gen. Tech. Rep. RMRSGTR-122. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain research Station. 15 p.

Keywords: habitat • measurement • seasonal variability • Columbia River Basin.

Abstract : We evaluated sampling variability of stream habitat sampling methods used by the USDA Forest Service and the USDI Bureau of Land Management monitoring program for the upper Columbia River Basin. Three separate studies were conducted to describe the variability of individual measurement techniques, variability between crews, and temporal variation throughout the summer sampling season. We quantified the variability between crews and through time, and described the percent of the total variability attributed between crew and seasonal variability. We then estimated the number of samples needed to detect change between managed and reference sites. Differences among streams accounted for a larger share of the total variability than did differences among observers. Stream variability was greater than 80 percent of the total variability for 12 of the 16 variables measured. This is somewhat surprising given the similarities between the study streams. Observer variability was minimal for stream habitat methods describing reach, streambank, and cross-section variables. Conversely, variability was higher for pool, large woody debris, and substrate variables. Seasonal variation was minimal for stream channel variables with the exception of substrate particle sizes. Sample sizes derived from both observer and stream variability (type I error 0.1, type II error 0.9, minimum detectable change 10 percent) ranged from 10 to 3,502 sites to detect changes between two populations. We believe that these estimates represent an unambiguous and powerful way to display the consequences of variability to scientists and managers.

- 259 - Avery E.L., 2004. A Compendium of 58 Trout Stream Habitat Development Evaluations in Wisconsin–1985-2000[1]. Report 187. Waupacac, WI, Wisconsin Department of Natural Resources-Bureau of Integrated Sciences Services. 97p.

Abstract : A standard format was devised to summarize 58 trout stream habitat evaluations carried out by Wisconsin Department of Natural Resources biologists and University of Wisconsin- Milwaukee staff on 53 streams distributed among 25 counties during 1985-2000. The success of each project was judged on the basis of the percent change within a treatment zone for 4 categories (or population variables): 1) total number of trout, 2) number of trout ≥6 inches, 3) number of legal size trout, and 4) total biomass (pounds per mile). Standardization was at a “per mile” basis. Two levels of success were determined: Level 1= post-development increases in the population variable of 25% or more and Level 2= increases in the population variable of 50% or more. Approximately 59% of the changes in 140 population variables analyzed had Level 1 success after habitat development; 50% had Level 2 success. Total abundance of trout met Level 1 success in 43% of the treatment zones. Success rate at Level 2 was found in 31% of the treatment zones. Abundance of legal size trout achieved success rates of 65% and 62% at Levels 1 and 2, respectively. In treatment zones with allopatric populations of brook trout or brown trout, success rates were similar. In sympatric populations, brown trout responded much more positively than brook trout did to habitat development. Habitat development techniques employed were grouped into 9 categories based on the predominant techniques. The beaver dam removal category, in treatment zones supporting allopatric brook trout populations, achieved the highest success rates. In sympatric trout populations, the “Wisconsin-style” bank cover and current deflector category achieved the best success rates. The channel excavation with whole log cover and boulders category achieved good results regardless of the trout species present. The bank cover logs and current deflectors category achieved excellent success in high gradient (1-3%) streams. Average empirical post-development changes for populations of trout in 58 treatment zones included a 13% decline in total abundance of trout (from 1,323 per mile to 1,125 per mile), a 65% increase in trout ≥6 inches (from 208 per mile to 344 per mile), a 25% increase in legal size trout (from 291 per mile to 363 per mile), and a 63% increase in biomass (from 100 lbs. trout per mile to 163 lbs. trout per mile. Elements of this study and a similar Wisconsin study from 1953-85 were consolidated to provide 103 case histories detailing the results of habitat development on 82 different trout streams in

36 Wisconsin counties. Composite analyses not only provide near identical (Levels 1 and 2) success rates for 244 trout population variables but also provide fisheries managers with habitat development choices segregated by regions in the state.

[1] Includes one study completed during 1964-67.

- 260 - Bayley P.B., 2002. A review of studies on responses of salmon and trout to habitat change, with potential for application. in the Pacific Northwest. Report to the Washington State Independent Science Panel, 38 p.

Abstract : An inspection of abstracts from 2,350 references produced a first-cut set of 441 studies and reviews that were subsequently classified and reviewed with respect to their potential to document responses of salmonids to habitat changes, and to guide future monitoring of salmonid watersheds. Although the literature on habitat requirements is vast, it was necessary to distinguish between studies that relied on correlations based on observational designs and those which attempted experimental designs to test cause-and-effect mechanisms. Our understanding about environmental effects on fish is largely based on weak inferences from observational studies, which has a direct bearing on monitoring strategies. Such studies are useful in generating hypotheses on cause-and-effect, but such hypotheses need to be tested through appropriate experimental designs in the context of a validation monitoring approach. Findings from seven reviews (1988-2002) were assessed jointly with specific studies. Articles from 30 studies were reviewed, drawing from single or multiple streams, and purely observational or 'natural experiment' designs, in order to assess what improvements are needed in future programs. Relatively few studies were long term or from multiple watersheds; most studies were of one year or spanned a single generation. Although large-spatial scale, short-term studies have increased and provided insight into clustering of populations and dependency on environmental indicators at broader scales, there is no indication of the extent to which space can be traded for time when making inferences. The main technical deficiencies were the lack of concern about unbiased density estimates and poor statistical design, analyses and reporting. Analyses that simulate alternative sampling processes and expected biases in stream networks over time and space would help resolve some of these deficiencies. Overall, I concluded that current freshwater-based monitoring programs will either: (1) fail to indicate an improvement associated with stream habitat restoration in terms of smolt recruitment, returning adults, or population size increase at the watershed scale, or (2) indicate an improvement but fail to demonstrate which and how habitat changes were responsible so that subsequent restoration policy could be made more cost-effective. Recommendations for approaches to a large-scale monitoring design, based partly on this review are presented. The first-cut list of references, with abstracts and classification codes, is available electronically from the author.

- 261 - Cottingham P., Bond N., Lake P.S., Arthington A. & Outhet D., 2005. Recent lessons on river rehabilitation in eastern Australia.Technical Report. CRC for Freshwater Ecology, Canberra, ACT., 81p.

Abstract : It is widely recognised that many of Australia's rivers have been adversely affected by intensive human impacts. This has resulted in the implementation of hundreds of river rehabilitation projects over the last two decades, with millions of dollars spent annually. However, rehabilitation projects are rarely evaluated, making it difficult to determine if particular management or rehabilitation actions are successful. Unfortunately, experience both in Australia and overseas suggests that many rehabilitation projects fail to achieve their stated ecological objectives. Halting or reversing the decline in river condition will require long-term commitment and will also require the use of best available information on where and what type of rehabilitation activity is best suited to the circumstances. There is also a need to learn from recent rehabilitation efforts so that insights and lessons can be applied elsewhere and the best use made of available resources and knowledge. This report describes some of the key findings gained from rehabilitation experiments and research projects conducted on rivers in temperate and arid regions in eastern Australia. The lessons learnt are then considered within the context of the design, implementation and/or evaluation of a river rehabilitation project. A number of valuable technical manuals are already available to help practitioners plan and implement their rehabilitation projects (these are cited in the body of this report). This report seeks to complement such volumes (rather than present another complete 'how-to' manual) by capturing recent lessons to have emerged from the Cooperative Research Centre (CRC) for Freshwater Ecology and associated

research, and from the experience of research staff and associated practitioners engaged in river rehabilitation and management in eastern Australia. The 'boom–bust' nature of many river systems in Australia is well known. Riverine communities of plants and animals have evolved to be dynamic, rather than stable, in space or time. Investigations of riverine community response to disturbance, including succession and dispersal patterns of biota and changes to ecosystem functions such as productivity and respiration, provided valuable insights that can assist river rehabilitation efforts in the future. A key attribute of healthy river systems is their resilience to disturbance. Ultimately, rehabilitation aims to increase resilience in degraded systems by contributing to their capacity to withstand natural and further human-induced disturbances and reorganise while undergoing change so as to retain essentially the same function, structure, and feedbacks as the predisturbed state. A key consideration for those undertaking river rehabilitation is to consider carefully how, in space and time, their projects might be affected by largescale factors, such as climatic extremes and catchment land-use. How might these large-scale factors affect the outcomes anticipated from rehabilitation activities? Experience in many river systems has also highlighted that the drivers of stream condition can be distant from the locality where ecosystem impacts are evident. Most rehabilitation projects conducted in Australia to date have focused on small-scale issues (e.g. reach, or even local site scale activities such as reinstating physical habitat features). A key question must be 'does the scale of the proposed rehabilitation works match that of the drivers of ecosystem condition?'.

- 262 - Everest F.H., Sedell G.H., Reeves G.H. & Wolfe J., 1985. Fisheries Enhancement in the Fish Creek Basin; Evaluation of In-Channel and Off-Channel Projects, 1984 Annual Report. Report DOE/BP/16726-1.

Abstract : This S-year project which began in 1983 is designed to construct and evaluate habitat improvements in the Fish Creek basin by personnel of the Estacada Ranger District, Ht. Hood National Forest, and the Pacific Northwest Forest and Range Experiment Station. The work is jointly funded by BPA and USDA-Forest Service. The evaluation has focused on activities designed to improve spawning and rearing habitat for chinook and coho salmon and steelhead trout. Specific habitat improvements being evaluated include: boulder berms, an off-channel pond, a side-channel, addition of large woody debris to stream edge habitats, and hardwood plantings to improve riparian vegetation. The initial phases of habitat work have proceeded cautiously in concert with the evaluation so that knowledge gained could be immediately applied to future proposed habitat work. The evaluation has been conducted at the basin level, rather than reach or site level, and has focused intensely on identification of factors limiting production of salmonids in Fish Creek, as well as physical and biological changes resulting from habitat improvement. Identification of limiting factors has proven to be difficult and requires several years of all-season investigation. Results of this work to date indicate that spawning habitat is not limiting production of steelhead or coho in the basin. Coho habitat is presently underseeded because of inadequate escapement. Key summer habitats for coho, age 0 and age 1+ steelhead are beaver ponds, side channels, and pools, respectively. Key winter habitats appear to be groundwater-fed side channels and boulder-rubble stream margins with 30+ cm depth and low velocity water. Additional work is needed to determine whether summer habitat or winter habitat is limiting steelhead and coho production. Chinook use of the basin appears to be related to the timing of fall freshets that control migratory access into the system. Instream habitat improvements show varying degrees of promise for meeting their Intended objectives, but all will require some modification to the original design for future use. Boulder berms designed to increase spawning habitat have already Impounded small amounts of gravel and are providing spawning areas for steelhead. Some winter habitat was lost, however, due to construction at each berm site. An off-channel coho rearing pond produced a few exceptionally large coho smolts the first year after construction. A side channel development was used by spawning coho and chinook soon after construction in 1984, but few juvenile salmonids were found there in the winter of 1984-85. It is too soon to evaluate riparian plantings or addition of woody debris to stream edges. Comprehensive benefits or losses are difficult to determine for projects only one or two years old since fish response to improvements often takes several years. The success of each improvement must be measured in terms of increased smolt outputs. Our work indicates that the risk of failure associated with habitat improvement projects is very high without: (1) a detailed analysis of limiting factors in a basin, and (2) an evaluation of physical and biological changes in a basin, including smolts produced, resulting from improvements.

- 263 - Fjorback C., Pedersen L.M., Kronvang B. & Friberg N., 2002. Can the RHYHABSIM model be applied for evaluation of habitat improvement following river restoration : case of remeandring the river Gels, Denmark. Enviro Flows 2002 4Th Ecohydraulics, 14p.

Keywords: river restoration • effects • trout habitat • hydraulic-habitat model.

- 264 - Gerstein, J.M. 2005. Monitoring the Effectiveness of Instream Habitat Restoration. University of California, Center for Forestry, Berkeley, CA. 45 pp.

- 265 - Gerstein, J.M., W. Stockard and R.R. Harris. 2005. Monitoring the Effectiveness of Instream Substrate Restoration. University of California, Center for Forestry, Berkeley, CA. 53 pp.

- 266 - Gerstein, J.M. and R.R. Harris. 2005. Protocol for Monitoring the Effectiveness of Bank Stabilization Restoration. University of California, Center for Forestry, Berkeley, CA. 24 pp.

- 267 - Hall J.D. & Baker C.O., 1982. Influence of forest and rangeland management management on anadromous fish habitat in western north America : Rehabilitating and Enhancing Stream Habitat: 1. Review and Evaluation. Pacific northwest forest and range experiment station. Forest Service, U.S. Department of Agriculture, Portland, Oregon.

Keywords : Fish habitat • habitat improvement • riparian habitat • anadromous fish • salmonids.

Abstract : The literature and many unpublished documents on rehabilitating and enhancing stream habitat for salmonid fishes are reviewed. The historical development and conceptual basis for habitat management are considered, followed by a review of successful and unsuccessful techniques for manipulation of spawning, rearing, and riparian habitat. Insufficient attention to evaluation of past work has slowed the development of habitat management for anadromous salmonids in the West. Recent developments, including improved design of structures to accommodate variable streamflow, show promise of permitting increased application of these techniques. Past work in the West has emphasized management of spawning habitat. We recommend increased emphasis on rehabilitation and enhancement of rearing and riparian habitat. The importance of a strong program of habitat protection is emphasized.

- 268 - Harris, R.R., C.M. Olson, S.D. Kocher, J.M. Gerstein, W. Stockard and W.E. Weaver. 2005. Procedures for Monitoring the Implementation and Effectiveness of Fisheries Habitat Restoration Projects. Center for Forestry, University of California, Berkeley. 24 pp.

Abstract : The procedures outlined here recommend qualitative implementation monitoring of all restoration projects. Qualitative effectiveness monitoring would be performed on 10 percent of all projects properly implemented every year. Qualitative monitoring of projects every year constitutes a methodology for assessing practices and would provide a basis for reporting on the overall performance of the FRGP. Quantitative monitoring of individual projects, groups of projects, and smaller watersheds would provide a more rigorous basis for judging the effectiveness of fisheries habitat restoration. Adoption and implementation of these recommendations might be facilitated by changes in the process by which proposals to the FRGP are written, evaluated and chosen. To allow monitoring, proposals and funded projects should include much more definitive information on project objectives i.e., quantified effectiveness criteria. There is also a need for directed research studies or analysis of existing data to provide information on natural variability in monitoring parameters. Also, every year there should be a process for determining which funded projects are monitored for quantitative effectiveness. Finally, some process must be established to provide data as a baseline for implementation and effectiveness monitoring. The basic design for quantitative monitoring is a BACI approach. This is theoretically the most appealing design and is generally being used in other states and for other programs in California.

- 269 - Hunt R.L., 1988. Compendium of 45 Trout Stream Habitat Development Evaluations in Wisconsin During 1953-1985. Technical Bulletin No. 126 1988. 80p, Federal Aid in Fish Restoration Act Project F-83-R.

Abstract : A standard case history format was devised to summarize 45 trout stream habitat evaluations carried out by Wisconsin Department of Natural Resources (DNR) fishery management and research biologists, on 41 streams distributed among 29 counties during 1953-85. Data were gathered from 55 treatment zones (TZs) averaging 0.84 mile long and 20 reference zones (RZs) averaging 0.74 mile long. Wild trout were dominant or solely present in 49 of the 55 TZs. ' Success ' of each project was judged on the basis of percentage changes within TZs for each of 6 possible variables standardized to ' per mile ' quantities. These 6 variables were: total number of trout, number 6 inches or larger (legal size), number 10 inches or larger (quality size), total biomass, angler hours, and angler harvest. Two arbitrary levels of success were set: level 1 = postdevelopment variable increases of 25% or more, and level 2 = increased of 50% or more. Approximately 60% of the quantified changes in the 6 standard variables exceeded success level 1 after habitat development; 43% exceeded success level 2. Postdevelopmental abundance of legal-sized trout was at least 25% greater than predevelopment abundance in 59% of the TZs where this variable was quantified. For projects involving allopatric populations of wild brook trout (Salvelinus fontinalis) or wild brown trout (Salmo trutta), success rates were similar, but in sympatric situations brown trout responded much more positively than did brook trout to habitat development. The ' Wisconsin-style ' bank habitat development technique cover and current deflector category generally produced the best success rates. Stream bank debrushing, sometimes in combination with installation of brush bundles, was very effective in a few TZs but scored low in overall success rates for all 9 TZs. Projects initiated after 1977 (post-trout-stamp era) were slightly more successful than projects initiated prior to 1977. (Lantz-PTT)

- 270 - Hunt R.L., 1992. Evaluation of Trout Habitat Improvement Structures in Three High-Gradient Streams in Wisconsin. Department of Natural Resources, Madison, WI Technical Bulletin No. 179, 40p.

Abstract : Eight types of in-channel trout habitat improvement structures were installed in 3 treatment zones (TZs) on portions of 3 Wisconsin trout streams having TZ gradient of approximately 1% (53-72 ft/mi). Structures were installed in the TZs at densities of 142/mi in Camp Creek, 100/mi in Devils Creek, and 208/mi in Twenty Mile Creek. Most of the wood and rock used to build the structures were gathered on site. Approximately 63% of the 72 test structures provided good or excellent trout habitat 4 yrs after installation. Two structure types, the channel constrictor and the cross-channel log/bank revetment, provided consistently good habitat for adult trout. Durability and functional performance of structures were much better in the 2 smaller TZs, on Camp Creek and Twenty Mile Creek, than in the largest TZ on Devils Creek. Only the channel constrictor and some bank cover logs functioned effectively in the Devils Creek TZ. Average cost per structure was $230 for the 2 smaller TZs on Camp and Twenty Mile creeks. Project cost per mile was approximately $38,000 (165 structures/mi). Wages for the professional crew accounted for 65% of the total cost. Abundance and biomass of wild brown trout (Salmo trutta) in April increased significantly in the Camp Creek TZ (1984 vs 1985-89 average), despite unfavorable below-normal streamflow regimes during the last 2-3 yrs of the post-installation period. Density of legal sized trout peaked at 457 trout/mi; biomass peaked at 344 lb/mi. Spring and fall densities of legal sized brown trout and total biomass in the spring and fall declined in the reference zone (RZ) during the post-installation period. At Devils Creek, densities of wild brook trout (Salvelinus fontinalis) and domestic brown trout in September were sparse in both the TZ and the RZ throughout the evaluation, due to lack of natural recruitment. At Twenty Mile Creek, legal sized wild brook trout (>/= 6 in) increased an average of 118% (to 185 trout/mi) in the TZ (1983-85 vs. 1986-89) and peaked at 392 trout/mi in September 1986. In the adjacent RZ, no change occurred in average density (189 trout/mi) of legal sized brook trout. Fisheries management recommendations include use of 7 of the 8 test structures to improve trout habitat in other small high gradient streams in Wisconsin and greater use of volunteer labor to reduce project costs. (Lantz-PTT)

- 271 - Keeley E. R., Slaney P.A. & Zaldokas D., 1996. Estimates of production benefits for salmonid fishes from stream restoration initiatives. Province of British Columbia, Ministry of Environment, Lands and Parks, and Ministry of Forests. Watershed Restoration Management Report 4: 22 p.

Abstract : We collected and summarized data from 30 studies from the literature to assess the effects of stream restoration efforts on densities of salmonid fish and therefore potential production benefits. This synthesis indicates, in general, that stream restoration efforts provide significant increases in the densities of salmonid fish in streams. This was true for both the juveniles of anadromous salmonids (coho salmon, chinook salmon, and steelhead trout) and total numbers of non-anadromous or resident salmonids (brook, brown, cutthroat and rainbow trout). Similarly, the numbers of catchable-sized resident fish (≥ 15 cm) also appear to increase significantly after stream rehabilitation. Areas of spawnable gravel tend to increase from restoration efforts which should provide more area for spawning fish. Provided assessments of limited spawning area are accurate, restorations may increase the numbers of anadromous salmonids that spawn but do not rear in streams for extended periods (chum, pink and sockeye salmon). Artificially created or newly opened off-channel habitat (side channels and ponds) also provides significant areas for spawning and rearing, providing an average of 225 migrating chum fry /m^2, and 0.67 coho salmon smolts /m^2. We used average changes in fish densities and life-stage survival rates to calculate potential increases in adult numbers as a result of stream restoration efforts. Assuming changes to stream densities translate into increases in adult numbers, then coho salmon, chinook salmon, and steelhead trout adults should increase on average by 123 %. If the reported 8-fold increase in spawnable gravel translates into increased production of chum, pink and sockeye salmon, then adults produced per m^2 of stream should increase on average from 0.39 to 3.37 per m^2 of stream (88%). Juvenile and catchable-sized resident salmonids (brook, brown, cutthroat and rainbow trout) should increase on average from 25 to 73%. Finally, off-channel habitat may potentially produce 1.58 chum salmon adults and 0.066 coho salmon adults per m^2 of side channel and 0.068 coho salmon adults per m^2 of off-channel pond.

- 272 - Kershner, Jeffrey L.; Archer, Eric K.; Coles-Ritchie, Marc; Cowley, Ervin R.; Henderson, Richard C.; Kratz, Kim; Quimby, Charles M.; Turner, David L.; Ulmer, Linda C.; Vinson, Mark R. 2004. Guide to effective monitoring of aquatic and riparian resources. Gen. Tech. Rep. RMRS-GTR-121. Fort Collins, CO: U.S. Department of Agriculture, Rocky Mountain Research Station. 57 p.

Keywords: effectiveness monitoring • stream habitat • riparian habitat • monitoring strategy • aquatic sampling • vegetation sampling • watershed conditions • critical riparian area.

Abstract : This monitoring plan for aquatic and riparian resources was developed in response to monitoring needs addressed in the Biological Opinions for bull trout (U.S. Department of the Interior, Fish and Wildlife Service 1998) and steelhead (U.S. Department of Commerce, National Marine Fisheries Service). It provides a consistent framework for implementing the effectiveness monitoring of aquatic and riparian resources within the range of the Pacific Anadromous Fish Strategy (PACFISH) and the Inland Fish Strategy (INFISH). The primary objective is to evaluate the effect of land management activities on aquatic and riparian communities at multiple scales and to determine whether PACFISH/INFISH management practices are effective in maintaining or improving the structure and function of riparian and aquatic conditions at both the landscape and watershed scales on Federal lands throughout the upper Columbia River Basin. A list of attributes thought to be important in defining aquatic and riparian habitat conditions and their relationship with listed species were identified. The list of attributes was then translated into measurable criteria and compiled to form sampling protocols for both stream channel parameters (Part II) and vegetation parameters (Part III). These sampling methods were tested for variability, and the results are documented in two other publications “Testing Common Stream Sampling Methods for Broad-Scale, Long-Term Monitoring.” (Archer and others 2004) and “The Repeatability of Riparian Vegetation Sampling Methods: How Useful Are These Techniques for Broad-Scale Monitoring?” (Coles-Ritchie and others, in preparation).

- 273 - Lister D.B. & Bengeyfield W.E., 1998. An assessment of compensatory fish habitat at five sites in the Thompson River system. Can. Manuscr. Rep. Fish. Aquat. Sci./Rapp. Manuscr. Can. Sci. Halieut. Aquat. no. 2444, 73 p.

Abstract : Compensatory fish habitat was created at 5 sites on the Thompson and North Thompson rivers in British Columbia to offset impacts of highway and railway improvements on juvenile and adult salmonid habitat. Three of the cases involved development of new wetland pond and stream habitat, while the other 2 cases entailed re-creation of maistream river embayments with rock spurs. Habitat at each site was initially subjected to post-construction monitoring for 1-4 years. The follow-up study, conducted 5-12 years after habitat development, involved a low-intensity monitoring effort to assess the continuing effectiveness of the compensatory habitats. At 4 of 5 study sites the compensatory habitat was functioning to effectively offset the original impacts. The single exception was a wetland pond complex where habitat quality was declining as a result of pond infilling and organic enrichment from upstream sources in the watershed. The follow-up study also revealed that efforts to accelerate revegetation of wetland compensation sites had met with varied success. Natural colonization appeared capable of revegetating disturbed marsh and riparian areas in a relatively short time, and use of new habitat by juvenile salmonids, particularly coho salmon (Oncorhynchus kisutch), was not predicated on the existence of a restored plant community. The need for regular inspection and, as needed, maintenance of habitat structures was also identified. This follow-up study illustrated the value of periodic low-intensity monitoring to assess the continuing effectiveness of compensatory fish habitat.

- 274 - Northcote T.G., 1993. A review of management and enhancement options for the Arctic grayling (Thymallus arcticus) with special reference to the Williston Reservoir Watershed in British Columbia. Peace/Williston Fish and Wildlife Compensation Program, Report No. 78. 69pp.

Abstract : The biological and ecological features of Arctic grayling *(Thymallus arcticus)* relevant to its management and enhancement in British Columbia are reviewed over its range in North America as well as in Asia, and are compared to those for the European grayling *(Thymallus thymallus).* Populations of both species have declined in some areas where angling pressure has been severe and where major alteration of its habitat has occurred. However, native populations of Arctic grayling have become extinct in eastern parts of its North American range and nearly so in southwestern parts, whereas the range of European grayling has been extended, especially in the United Kingdom and in Finland, by introduction. Furthermore, in contrast to the Arctic grayling, the European grayling in Scandinavia at least, has been less severely affected by impoundment of rivers and lakes for hydroelectric generation, perhaps because it has been able to successfully reproduce in large rivers below dams. The success of various grayling management and enhancement practices, including hatchery culture and stocking, angling restrictions, spawning and rearing facilities, competitor and predator control, stream habitat restoration, lake and stream fertilization, and invertebrate prey introduction, are evaluated and compared for both species. A four-pronged approach for Arctic grayling management and enhancement in the Williston Reservoir watershed of British Columbia is recommended and includes: (1) filling gaps in knowledge of grayling biology locally and regionally; (2) limiting negative impacts of development on key grayling habitat; (3) applying appropriate management and enhancement practices on grayling populations, habitat, and sport fisheries in an adaptive and experimental manner; (4) providing the public with meaningful opportunities to understand and appreciate grayling and their habitat. Application of this approach is furthered by a set of specific recommendations.

- 275 - Roni P., 2001. Responses of fishes and salamanders to instream restoration efforts in western Oregon and Washington. Project completion report, 132p.

Abstract : Placement of large woody debris (LWD) into the active channel is one of the most common techniques for restoring and enhancing streams in the Pacific Northwest. However, the effectiveness of this technique at increasing fish and salamander abundance has not been consistently demonstrated. Thirty streams in western Washington and northwest Oregon were sampled during summer and winter to determine the responses of juvenile salmonids, juvenile lamprey (*Entosphenus tridentatus* and *Lampetra spp.*), sculpin (*Cottus spp.*) and giant salamanders (*Dicamptodon* spp.) to

artificial LWD placement and to examine their habitat preferences. In addition, to examine the effects of habitat modification on fish movements, I monitored the monthly movements of marked juvenile coho salmon (*Oncorhynchus kisutch*), steelhead (*O. mykiss*) and cutthroat trout (*O. clarki*) between a reach that had been "restored" (with placed wood) and a reference reach (no wood placement) in Shuwah Creek, Washington from September 1998 to April, 1999. I also examined the size, growth and movements of individually marked coho salmon among habitats in two artificial channels: one with and one without woody debris. Total pool area, pool number, LWD loading, and LWD forming pools were significantly greater in treatment (LWD placement) than paired reference reaches nearby during both summer and winter. Juvenile coho salmon densities were 1.8 and 3.2 times higher in treated reaches compared to reference reaches during summer and winter, respectively. The response (log10(treatment/reference)) of coho density to artificial LWD placement was correlated with the number of pieces of LWD forming pools during summer and total pool area during winter months. Densities of age 1+ cutthroat trout (*O.* viii *clarki*) and steelhead (*O. mykiss*) did not differ between treatment and reference reaches during summer but were 1.7 times higher in treatment reaches during winter. Age 1+ steelhead density response to treatment was negatively correlated with increases in pool area during summer, but not winter. Trout fry (age 0+ cutthroat and steelhead) densities did not differ between reaches, but trout fry response to treatment was negatively correlated with pool area during winter. This research indicates that artificial LWD placement can lead to higher densities of juvenile coho during summer and winter and cutthroat and steelhead during winter. In contrast to salmonids, no significant difference was detected between densities or mean lengths in treatment and reference reaches for giant salamanders, reticulate (*C. perplexus*) or torrent sculpin (*C. rhotheus*), or larval lamprey. However, lamprey response to LWD placement (treatment-reference) was positively correlated with LWD forming pools (treatment-reference). Difference (treatment – reference) in length of age 1+ reticulate sculpin was positively correlated with difference in LWD within the wetted channel. Species richness and dominance, two community diversity measures, did not differ between treatment and reference reaches. These results indicate that artificial LWD placement may benefit age 1+ reticulate sculpin and Pacific lamprey, two species known to prefer pools, but have little effect on other torrent sculpin or giant salamanders. Habitat use patterns for each species were examined at the scale of both individual habitat units and reaches. In the summer, densities of coho salmon, cutthroat trout, and larval lamprey were significantly higher in pools than riffles, whereas densities of age 0 torrent sculpin (*C. rhotheus*) were higher in riffles than pools. In winter, densities of coho salmon, cutthroat and steelhead trout, and young of the year trout fry ix were higher in pools than riffles. Cutthroat, steelhead, Pacific giant salamanders, and torrent sculpin found in pools were larger than those found in riffles. Multiple regression analysis indicated that physical variables (e.g., pool depth, cover, large woody debris, etc.) explained 10% or less of the variation in densities among pools. Reach-scale physical variables (e.g., elevation, drainage area, precipitation, stream gradient, percent pool area) explained from 22% to 63% of the variation of species density among streams. This suggests that reach-scale physical variables may be better predictors of fish densities among streams than variables measured within individual habitat units. Monthly surveys in Shuwah Creek to examine salmonid movement indicated that 0 to 33% (0 to 4 fish) of the marked trout or coho salmon observed on a given date moved between the restored and reference reach. However, the rapid decline in both marked and unmarked fish in late fall and the increasing proportion of unmarked fish over the course of the study indicated considerable migration to and from the study reaches. In the artificial channels, fewer fish moved in the simple (no wood) than the complex (with wood) channels (22% versus 37%, respectively), and the mean distance moved was shorter in the complex than the simple channel (4.4 versus 6.7 habitat units). In the simple channel, the fish that moved exceeded those that did not move in length, weight, and growth rate. We conclude that movement may facilitate increased growth in stream reaches with little woody debris and that the placement of woody debris may lead to more frequent and shorter movements. Movements of juvenile salmonids among stream reaches and individual habitats are common and need to be considered when evaluating restoration projects.

- 276 - Roni P., Hanson K., Beechie T., Pess G., Pollock M., Bartley D.M., 2005. Habitat rehabilitation for inland fisheries. Global review of effectiveness and guidance for rehabilitation of freshwater ecosystems. **FAO Fisheries Technical Paper. No. 484. Rome, FAO. 116p.** (ftp://ftp.fao.org/docrep/fao/008/a0039e/a0039e00.pdf)

Key words: habitat rehabilitation • restoration • fisheries • riparian • floodplain • monitoring and evaluation.

Abstract : The degradation of inland aquatic habitats through decades of human activities has lead to massive efforts to rehabilitate freshwater habitats for fisheries and aquatic resources in watersheds throughout the world. Many texts have been written on techniques for rehabilitation though no comprehensive worldwide review of the effectiveness of techniques has been undertaken. This paper reviews published evaluations of freshwater habitat rehabilitation projects, including studies on roads improvements and sediment reduction, riparian and floodplain rehabilitation, placement of habitat structures in lakes and streams, addition of nutrients to increase aquatic production and other less common techniques. In particular, the authors summarize what is known about the effects of various techniques for restoring natural processes, improving habitat, and increasing fish and biotic production. Recommendations on limitations of techniques, which techniques are effective, as well as information on planning, prioritizing and monitoring rehabilitation projects are also provided.

Despite locating more than 330 studies on effectiveness, as well as hundreds of other papers on rehabilitation, it was difficult to draw firm conclusions about many specific techniques because of the limited information provided on physical habitat, biota and costs, as well as the short duration and scope of most published evaluations. However, techniques such as reconnection of isolated habitats, rehabilitation of floodplains and placement of instream structures have proven effective for improving habitat and increasing local fish abundance under many circumstances. Techniques that restore processes, such as riparian rehabilitation, sediment reduction methods (road improvements), dam removal and restoration of floods, also show promise but may take years or decades before a change in fish or other biota is evident. Other techniques such as bank protection, beaver removal and bank debrushing can produce positive effects for some species but more often produce negative impacts on biota or disrupt natural processes.

Comparing the cost-effectiveness of different types of rehabilitation techniques was not possible because few evaluations reported various costs or economic benefits; however, estimates of average costs for various techniques are provided. Monitoring and evaluations clearly need to be designed as part of the rehabilitation action. The authors discuss the key steps to consider when designing monitoring and evaluation of rehabilitation actions at various scales.

Similar to less-comprehensive reviews of rehabilitation, this review demonstrates three key areas lacking in most rehabilitation projects: 1) adequate assessment of historic conditions, impaired ecosystem processes and factors limiting biotic production; 2) understanding upstream or watershed-scale factors that may influence effectiveness of reach or localized rehabilitation; and 3) well-designed and -funded monitoring and evaluation. These are the same factors that consistently limit the ability of published studies to determine the success of a given technique at improving habitat conditions or fisheries resources. Finally, this review suggests that many habitat rehabilitation techniques show promise, but most have not received adequate planning, monitoring or cost-benefit analysis.

- 277 - Scruton D.A.; Clarke K.D.; Anderson T.C.; Hoddinott A.S.; Van Zyll De Jong M.C. & Houston K.A., 1997. Evaluation of habitat improvement and restoration initiatives for salmonids in Newfoundland. Canada. Rapport manuscrit canadien des sciences halieutiques et aquatiques. Mar 1997.

Abstract : Declining Atlantic salmon Salmo salar stocks, which forced the closure of the commercial salmon fishery in Newfoundland in 1992, coupled with the increasing economic importance of the recreational salmonid fishery, has resulted in two major federal-provincial agreements over the past decade aimed at rebuilding the salmonid stocks. These agreements included habitat improvement and restoration as a major strategy and supported 142 projects. It was recognized that a proportion of these projects should undergo scientific evaluation to provide information on the effectiveness and transferability of techniques and to assist in developing region-specific criteria to guide publicly sponsored habitat initiatives. This report provides an overview of these evaluations, as selected case studies, including projects involving restoration of habitat degraded by historic forest harvesting, removal of a natural migration barrier, and the addition of spawning gravel to increase juvenile

production. Results of a series of experimnents in a controlled flow channel to investigate the effect of several habitat alterations on salmonid populations under Newfoundlan conditions are discussed. Generally, the projects evaluated have been successful in increasing salmonid abundance and/or production. Results highlight the importance of hydrological and biological considerations to habitat improvement and restoration initiatives.

- 278 - Smokorowski K.E., Withers K.J. & Kelso J.R.M., 1998. Does habitat creation contribute to management goals? An evaluation of literature documenting freshwater habitat rehabilitation or enhancement projects. Canadian Technical Report Fisheries and Aquatic Sciences No. 2249: vi + 74 p.

Abstract : Since the implementation of the "no net loss" policy for the management of fish habitat (DFO 1986), focus on fish habitat rehabilitation has sharpened. However, aquatic resource managers have implemented fish habitat rehabilitation, enhancement and creation efforts as a tool for ecological restoration for decades. Available published information from these past efforts to rehabilitate or create new freshwater habitat in a range of systems was reviewed in terms of cost, durability, aesthetics, side effects, method of assessment, and measurable benefits to aquatic ecosystems. Documentation of the 78 habitat rehabilitation projects was often poor with only 68% assessing costs, 4% considering aesthetics, and 24% considering side effects. Of the 30 projects (38%) that examined durability, 23 reported some type of structure deterioration. Only one example of a failed project was found in the published literature. Because 15% of the projects reviewed were incomplete (12 of 78), the success of those projects could not be assessed. Therefore the 65 completed projects, which reported to have achieved at least a portion of their habitat target (and were considered successful), implies a 98% habitat rehabilitation "success" rate (65 out of 66 completed projects). However in this sense, success was often measured in terms of achieving the habitat change without assessment of the biological benefit. An increase in fish production was detected for only four (5%) of the projects. A greater proportion of studies reported an increase in the biomass and/or abundance of target fish species (27%). However, generally, the source of the increase was not assessed – i.e. whether the increased biomass was produced by an increase in successfully growing and reproducing fish, or was it a redistribution/concentration of fish in the rehabilitated habitat. Evidence of redistribution/concentration was found in 17% of the projects. Improvements in assessment, monitoring, documentation and communication of results of rehabilitation projects are needed.

Résumé : Depuis la mise en oeuvre de la politique d' "aucune perte nette" pour la gestion de l'habitat du poisson (MPO, 1986), on travaille de façon plus ciblée au rétablissement de l'habitat. Toutefois, les gestionnaires des ressources aquatiques ont recours depuis des décennies au rétablissement, à la mise en valeur et à la création d'habitat comme outils pour la restauration du milieu naturel. Nous avons examiné l'information publiée sur les efforts déployés dans le passé pour rétablir ou créer de l'habitat dulcicole dans divers systèmes sur les plans du coût, de la durabilité, de l'esthétique, des effets secondaires, de la méthode d'évaluation et des effets positifs mesurables sur les écosystèmes aquatiques. La documentation des 78 projets de rétablissement était souvent médiocre : 68 % seulement évaluaient les coûts, 4 % s'intéressaient à l'aspect esthétique et 24 % aux effets secondaires. Sur les 30 projets (38 %) qui examinaient la durabilité, 23 ont signalé une forme de détérioration des structures. Un seul exemple d'échec est décrit dans la littérature. Étant donné que 15 % des projets examinés n'étaient pas achevés (12 sur 78), il a été impossible d'évaluer leur degré de réussite. Les 65 projets achevés, pour lesquels la cible a été atteinte au moins en partie (et qui sont considérés comme des réussites), donnaient un taux de "succès" de 98 % dans le rétablissement de l'habitat (65 projets sur 66 menés à terme). Toutefois, on mesurait souvent le succès en termes de changements apportés à l'habitat, sans évaluation des effets sur le plan biologique. Une augmentation de la production de poissons a été observée dans 4 % seulement des projets. Une plus grande proportion des études rapportaient une augmentation de la biomasse et/ou de l'abondance des espèces de poissons cibles (47 %). Toutefois, dans l'ensemble, la source de cette augmentation n'était pas évaluée – l'augmentation de la biomasse était-elle causée par un accroissement du nombre de poissons qui réussissent à grandir et à se reproduire, ou s'agissait-il d'une redistribution/concentration des poissons dans l'habitat reconstitué? Il est nécessaire d'améliorer l'évaluation, la surveillance, la documentation et la communication des résultats des projets de rétablissement de l'habitat.

- 279 - Thorn W.C. & Anderson C.S., 2001. Comparison of two methods of habitat rehabilitation for brown trout in a southeast Minnesota stream. Minnesota Department of Natural Resources - Section of Fisheries, Investigational Report 488, 15 p.

Abstract : We evaluated habitat rehabilitation with overhead bank cover and woody debris for brown trout *Salmo trutta* under a no-kill regulation in two reaches of Hay Creek. In both treatment reaches and a downstream reference reach under normal fishing regulations, cover for trout increased, as did abundance and biomass of adult trout (age-1 and older). These habitat and population changes showed that the reference reach was not an independent control. Thus we used a regional database as our control. Comparisons with the regional database showed that the increases in abundance for the treatment reaches and the reference reach were due to improved habitat, and not natural fluctuations in abundance. Habitat rehabilitation was not as successful for larger trout. Abundance of trout longer than 300 TL mm did not significantly increase in either treatment reach. An increase was suggested in the reach improved with overhead bank cover; however, a fish kill prevented a complete evaluation. A habitat model for large trout suggested the probability of finding a trout longer than 380 mm TL should have increased in both treatment reaches after habitat rehabilitation, but abundance of trout longer than 380 mm TL did not increase. The failure to increase large trout abundance and the 25% decrease in mean asymptotic length suggest that forage and foraging sites limit abundance of large trout in Hay Creek. The potential of a stream to support rapid growth of trout may be critical to the production of more large trout in southeast Minnesota streams. The use of woody debris for habitat rehabilitation in southeast Minnesota moderately increased brown trout abundance, enhanced stream morphology in a flood-prone stream, and cost about one-third the cost of the intensive addition of cover structures. However, benefits from using woody debris were less because it produced fewer trout, will require more frequent maintenance, and has a shorter life expectancy. Benefits may be increased if more large wood is available to further increase debris cover. Habitat rehabilitation with abundant overhead bank cover and woody debris can be designed and evaluated with predictive models. We recommend including both abundant overhead bank cover and woody debris in habitat rehabilitation projects whenever feasible.

- 280 - Vehanen T., Huusko A., Yrjänä T., Lahti M. & Mäki-Patäys A., 2003. Habitat preference by grayling (*Thymallus thymallus*) in an artificially modified, hydropeaking riverbed: a contribution to understand the effectiveness of habitat enhancement measures. Journal of Applied Ichtyology, 19(1) : 15-20.

Abstract : This paper describes a case study to rehabilitate habitat for adult European grayling (*Thymallus thymallus* L.) in a large river reservoir in northern Finland. A channelled river reach was restored by building small islands and reefs as well as cobble and boulder structures for grayling. The total area of the restored stretch was 1.0 ha. The physical habitat was mapped using an echosounder, Doppler device, tachometer and scuba diving, and modelled with a 2D hydraulic model. The mean water velocity in the modelled stream section was 0.28 m s^{-1} during 110 m^3 s^{-1} flow and 0.43 m s^{-1} during 300 m^3 s^{-1} flow. Twelve adult grayling, tagged with transmitters, were released into the area and tracked for a maximum period of 30 days. The grayling largely stayed in the restored area and tended to avoid the unchanged channel of the river. The range of daily movement was from stationary to 2700 m per day. The adult grayling preferred water velocities between 0.20 and 0.45 m s^{-1}, water depths between 0.20 and 1.55 m and coarse substrate. The study provides a small part of the information needed in habitat restoration for grayling.

- 281 - Weaver, W.W., J.M. Gerstein and R.R. Harris. 2005. Monitoring the Effectiveness of Upland Restoration. University of California, Center for Forestry, Berkeley, CA. 100 pp.

- 282 - Wheaton JM, 2005. Review of river restoration motives and objectives. Unpublished Review, Southampton, UK, 12pp.

Bibilographies annotées:

- 283 - Bauer S.B. & Ralph S.C., 1999. Appendix D : Annoted bibliography. *For* : Aquatic habitat indicators and their application to water quality objectives within the clean Water Act. EPA-910-R-99-014. US Environmental Protection Agency, Region 10, Seattle Wa. 334 ref.

Abstract : This bibliography identifies 334 literature citations that are related to salmonid habitat. References have been categorized by subject group include : bank stability; channel morphology; classification and stratification; depth; dissolved oxygen; large woody debris, riparian, and cover; management; monitoring and data analysis; pools; references conditions, standards, and recommendations; restoration; species assemblages; species prferences; substrate size and fine sediment; temperature; and velocity and flow. Many of the references provide an abstract of the article.

- 284 - Keim R.F., Price A.B., Hardin T.S., Skaugset A.E., Bateman D.S., Gresswell R.E. & Tesch S.D., 2003. An Annotated Bibliography of Selected Guides for Stream Habitat Improvement in the Pacific Northwest. Research Contribution 44, Forest Research Laboratory, Oregon State University, Corvallis.

Keywords: aquatic habitat • fisheries • restoration • salmonids • stream management.

Abstract : This annotated bibliography is a response to widespread interest in stream habitat improvement in the Pacific Northwest by land managers, governmental and nongovernmental organizations, and the lay public. Several guides to stream habitat improvement have been written in the past, but may not be easily accessible to people from diverse backgrounds. This annotated bibliography reviews 11 guides to stream habitat improvement so that readers can find literature appropriate to their needs. All reviews begin with summaries of the contents, stated audiences, and goals of each guide. Reviews also include subjective comments on the strengths and weaknesses of each guide. Finally, this bibliography includes recommendations of guides and combinations of guides judged most useful for a range of purposes.

- 285 - Lassettres N.S., 1999. Annoted bibliography on the ecology, management, and physical effects of large woody debris (LWD) in stream ecosystem. Department of landscape architecture and environmental planning. University of California, Berkeley. Prepared for the California department of forestry. 279 ref.

Ressources électroniques :

Sites consacrés aux connaissances relatives à la restauration des milieux, sites plates fomes :

http://restoringrivers.org/ : nombreux exemples nord américains et liens vers d'autres sites.

http://www.ecrr.org/ : european center for river restoration.

http://www.ser.org. : Society of ecological restoration international.

http://www.therrc.co.uk/ : The river restoration center.

http://www.milieuxaquatiques.com/telechargement.htm.

http://www.gesteau.eaufrance.fr/spip/spip.php?rubrique19 : exemples d'opérations de protection et de restauration de milieux aquatiques pour lesquelles des évaluations de la qualité des milieux, avant et après travaux, sont disponibles.

http://www.joewheaton.org.uk/Rivers.asp.

http://www.rivermanagement.ch/ : Présentation des résultats et enseignements tirés du projet de recherche Rhône-Thur (site et majorité des documents en Allemand)

Guides techniques disponibles sur internet (conception et suivi) :

FISRWG, 1998. **Stream corridor restoration : principles, processes, and practices.** By the Federal Interagency Stream Restoration Working Group (15 Fedral agencies of the US gov't). GPO Item 0120-A SuDocs No. A 57.6/2:EN3/PT.653. (http://www.nrcs.usda.gov/technical/stream_restoration/)

Saldi-Caromile K., Bates K., Skimore P., Barenti J. & Pineo D., 2004. **Stream habitat restoration guidelines :** final draft. Co-published by the Washington Departments of Fis hand Wildelife and Ecology and the U.S. Fis hand Wildlife Service. Olympia, Washington. (http://wdfw.wa.gov/hab/ahg/shrg/index.htm).

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Retours d'expériences français et francophones.

Agence de l'eau RMC (Adam P., Malavoi J.R. & Debiais N.), 2006**. Retour d'expérience d'opérations de restauration de cours d'eau et de leurs annexes, menées sur le bassin RMC.** Rapport n°05.079-ETU-101, 129p.

Agence de l'eau Rhin-Meuse (Lebreton M.), 2004. **Retour d'expériences des travaux de renaturation réalisés sur des émissaire agricoles du bassin Rhin-Meuse.** 170p.

Agence de l'eau Seine Normandie (Adam, Ph., Malavoi, J.R. & Debiais, N.), 2007. **Manuel de restauration hydromorphologique des cours d'eau.** *DEMAA - Service eaux de surface.* Manuel : 61 p.; fiches techniques : 100 p.

Association Truite-Léman, 2004. **Projet pilote : suivi du Boiron de Morges : rapport 2003-2004.** 65p.

Association Truite-Léman, 2002. **Synthèse du suivi biologique du Boiron 1996-2002.** 242p.

Caudron A., Josserand Y. & Genevey G., 2002. **Amenagement d'une zone de reproduction pour la truite fario sur la resurgence de Morette : rapport de présentation des travaux – évaluation et suivi de l'aménagement.** Rapport FDP74.02/10, 13p + annexes.

Caudron A. & Dufaux E., 2003. **Réhabilitation d'un tronçon recalibré sur la Veïse (commune de Gruffy) : rapport de présentation et de suivi des travaux.** Rapport FDP74.03/01, 14p.

Caudron A. & Dufaux E., 2003. **Restauration de cours d'eau et aménagements piscicoles : présentation de quelques réalisations.** 1eres journées d'échanges techniques, 16-19 juin 2003. Rapport FDP74.03/03. 63p.

CSP, DR de Metz, Pierron F. & Monnier D., 2005. **Restauration physique des cours d'eau dans le nord-est de la France.** 17p.

CSP (Hydrosphère), 2004**. Evaluation du coût de création d'un écosystème fonctionnel en cours d'eau.** 24p. + annexes.

David (2006) **Suivi environnemental sur un cours d'eau cotier morbihannais : la Drayac.** Rapport de stage, 66p.

FDPPMA 56 (2002) **Réhabilitation d'habitats piscicoles sur le ruisseau du Langonnet ; 1ère phase : Etat des lieux, diagnostic, et faisabilité.** Rapport CPER 2000-2006, 42p.

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GIREA-Namur & Laboratoire d'Hydrographie et de Géomorphologie fluviales-ULg, 2003. **Suivi écologique et géomorphologique des chantiers de techniques végétales, exemples de la Semois à Etalles et de l'Ourthe à Moircy.** Rapport final, Service des Cours d'Eau Non Navigables, Région Wallonne, 109-128

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Syndicat mixte de la vallée du Drugeon et du plateau de Frasne (Teleos), 2001. **Estimation des gains biologiques et morphodynamiques obtenus par la restauration du Drugeon : suivi 2000.** 58p. + annexes.

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