Green Links and Urban Biodiversity—an Experiment in Connectivity

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Abstract
Many cities are located on estuaries, floodplains or other biologically productive and unique habitats. Natural ecosystems are fragmented in urban areas and are increasingly isolated as cities densify to accommodate population growth. Greenways are one approach to maintain natural connections, thereby preserving larger breeding populations of plants and animals and more robust food webs. The Green Links Project in Greater Vancouver improves connectivity by planting native vegetation to strengthen wildlife corridors. Plantings take place in utility rights-of-way, riparian zones of streams, backyards and hedgerows. Public participation is encouraged. Green Links works with municipalities to add ecological value to greenways, including them in a strategy to conserve biodiversity as well as providing public transportation, recreation opportunities and aesthetics to the community.

Introduction
Green Links is a project that strengthens connections between ecosystem fragments in urban environments. Cities often occur in unique and valuable natural ecosystems such as the Fraser River estuary and delta (a major stopover on the Pacific Flyway for migrating birds, and the site of the world's largest salmon run) in the case of Greater Vancouver, British Columbia, or the Garry Oak Woodlands in Greater Victoria. Urbanization creates fragments of natural habitat that are subsequently often identified as environmentally sensitive areas in planning documents. These fragments individually still contribute to the value of the greater ecosystem in which they occur. However, as they are increasingly isolated through continued urbanization their value as natural areas is diminished further, even though they may be protected in parks; they will still look green but will not support as much biodiversity. Connecting fragments with "Green Links" enables them to function as more viable larger units, thereby helping to protect their biodiversity.

The loss of important habitat due to urbanization is considerable. In the United States from 1959 to 1982, 22 million acres of land were converted to urban and other developed land uses, an increase of 45% (Heimlich and Anderson 1987). In the Lower Mainland of British Columbia, land that has been converted to agriculture or other similarly cultivated landscapes has only 50% of the average net primary productivity of original forested ecosystems and urban landscapes have only 13% (Healey 1997). The natural ecosystems surviving are often fragmented and isolated with reduced biodiversity and a loss in viability. Fragmentation also facilitates the spread of invasive alien species (Wilcox and Murphy 1985).

The fragmentation of important natural ecosystems by urban development leads to habitat loss and isolation, and is considered to be perhaps the greatest threat to biological diversity (Harris 1989; Wilcox and Murphy 1985; Brown et al. 1991). Wildlife (non domestic plants and animals) population sizes decrease, local extinctions increase, and isolation interferes with recolonization of highly productive habitat (MacArthur and Wilson 1967; Opdam 1991).

When cities occur in such important natural locations, their limited natural areas may be significant to wildlife and in providing nature's services for people, despite their small size and high levels of disturbance (Schaefer 1994). Urban forests, for instance, play a crucial role in maintaining water quality, loafing grounds, feeding grounds, perch sites, ambient temperature, buffer strips and other important factors that contribute to the overall health of an ecosystem.

Connectivity
One approach to the problem of habitat fragmentation is connectivity. Drawing on the theory of island biogeography and conservation biology, fragments are connected to enable them to function as larger units with larger breeding populations and more complex food webs. The habitat fragments are seen as nodes in a network, which includes a matrix of connections between them.

The strength and impact of network connectivity can be determined by the number of networks in a region, the dimensions of the links within the networks and the number and sizes of the nodes (Linehan et al. 1995). The value of connectivity in forestry conservation and facilitating the movement of wildlife between patches of habitat is generally accepted (Harris 1984; Noss 1987), even though it is difficult to predict if a link will function as expected (Simberloff

and Cox 1987). Having a corridor of adequate dimensions may in itself be insufficient (Henein and Merriam 1990). Wildlife movement through corridors has been demonstrated for small and large mammals (e.g Wegner and Merriam 1979) and for birds (e.g. Dmowski and Kozakiewicz 1990). The best wildlife corridors have good vegetation layering, a diversity of plant life and a minimum of invasive alien species (Thorne 1993).

Greater Vancouver has many ecosystem fragments. On the Burrard Peninsula alone large fragments of 400 or more hectares are found in Stanley Park, Pacific Spirit Regional Park, the central valley of Burnaby with Burnaby Lake and Deer Lake, and Burnaby Mountain itself, to name a few of the most obvious. Burns Bog in Delta is over 4,000 ha in area and represents a rare peat bog formation. Greater Vancouver also has over 140 urban ravines, collectively representing a linear distance of 98.5 km and an area of 11.5 square km of forested habitat (Schaefer et al. 1992).

In wilderness forest ecosystems, connectivity is established by deliberately leaving connections of unlogged stands between nodes. In urban systems links may remain as riparian corridors in the form of leave strips along urban salmon streams as specified by the Department of Fisheries and Oceans. In most cases, however, links need to be created from disturbed habitat or as part of a development plan such as greenways in a community. This can be accomplished through community stewardship and through the planning efforts of landscape architects to increase the structural complexity of vegetation. The best wildlife corridors have good vegetation layering, a diversity of plant life and a minimum of invasive alien species (Thorne 1993). Having a corridor of adequate dimensions may in itself be insufficient (Henein and Merriam 1990).

The value of greenways to ecosystem function has been actively cultivated and several case studies have been described such as the southwestern Wisconsin environmental corridors and the Boulder greenways (Smith and Hellmund 1993). A greenway that emphasizes ecological benefits is classified as a third generation greenway (Searns 1995). Urban ravines provide excellent opportunities for connectivity and are sometimes conserved and enhanced as such in Toronto.

The Green Links Project

The goal of the Green Links Project is to maintain the viability of natural ecosystem fragments in urban areas and to use a holistic approach which involves the community. A Green Link is a type of greenway but it differs from most in that the movement of people is not an essential part of the design, enabling backyard habitat to be incorporated. Backyards have an important role to play in connectivity (Rudd et al. 2002) (Figure 1).

Habitat fragmentation is a problem in Greater Vancouver. Over the past 10 years the region has grown to 2.1 million people, with the population expected to almost double to 3.1 million people by the year 2021. The Greater Vancouver Regional District's response to this rapid growth (GVRD 1995) is the "compact metropolitan model." This concentrates future growth into regional centres in Vancouver, Coquitlam, Burnaby, New Westminster and North Surrey/North Delta. This plan protects the Green Zone around Greater Vancouver. However, if left unchecked, this strategy can contribute to the already advanced state of fragmentation in the Lower Mainland's wildlife habitats.

Green Links considers both wildlife and human values because, although important wildlife habitat occurs in cities, the primary land-uses are primarily economic, social and cultural. Environmental education and publications highlight the diversity and value of natural habitat in developed urban landscapes. Green Links is a relatively new approach in its holistic strategy encouraging both concrete action such as habitat restoration, and a change in values (through writings and art) resulting in more environmentally sustainable lifestyles.

Methods

Links are established by increasing biodiversity in existing or new corridors through plantings of native vegetation (primarily shrubs and perennials). The plantings are planned and organized to involve the community at large and organized groups such as service clubs (e.g. Optimists, Rotary), youth clubs (e.g. scouts, guides), municipal and regional governments (e.g. Burnaby, Coquitlam, Port Coquitlam, Surrey, Greater Vancouver Regional District) and nongovernmental environmental organizations (e.g. Vancouver Natural History Society, Burns Bog Conservation Society).

Green Links has three approaches to improve nature in the Greater Vancouver region:

Research: This highlights the extent of natural systems in the city and the role of urban biodiversity in maintaining community health.

Education: Our workshops, symposia, contests and public lectures are popular in raising awareness and

Figure 1. Before and after photographs of a backyard enhancement in Surrey.

concern for nature in the city. Bird and bat box workshops are especially of interest to schools. We also create interpretive signs in the links.

Stewardship: Plantings of native vegetation in stream corridors, utility rights-of-way, backyards, hedgerows and school grounds. Most of the plantings are done with community involvement, particularly schools. Several types of plantings are being used, depending on the conditions and requirements of each specific site. Various planting programs possible are:

- *Butterfly and hummingbird gardens* (herbaceous, low growing, plants).
- *Multiple species habitats* (incorporating shrubs such as native beaked hazelnut for Steller's Jay and squirrels).
- *Green space maintenance* (ground cover and shrubs to out compete nuisance species).

Stewardship also includes:

- Removal of invasive species such as Scotch broom.
- Constructing multiuse pathways.
- Refuse cleanups.

Two measures of biodiversity are being used. One is the Simpson's Index. The target is to use Green Links to raise the average biodiversity index (Simpson's) for birds (used as an indicator of overall biodiversity) by 30% (from 10 to 13) over a 10-year horizon, or an average of 3% per year in the short term. A second measure is the presence of indicator species. The assumption is that encouraging such species with more sensitive habitat requirements encourages more numerous species with less sensitive requirements. Examples of such indicator species may be dark-eyed junco (*Junco hymnals*) for ground cover, rufous-sided towhee (*Pipilo erythrophthalmus*) for shrub layer, rufous hummingbird (*Selasphorus rufus*) for nectar producing flowers, and yellow warbler (*Dendroica petechia*) for tree canopy habitat.

Green Links is primarily working in a number of sites. Two are utility corridors in Coquitlam and Surrey/Delta. Several are riparian corridors associated with streams of the Coquitlam and Fraser River watersheds. A few are hedgerows through agricultural fields in Delta. Then there are a number of residential plantings focused on backyards (Figure 1), school grounds and parks.

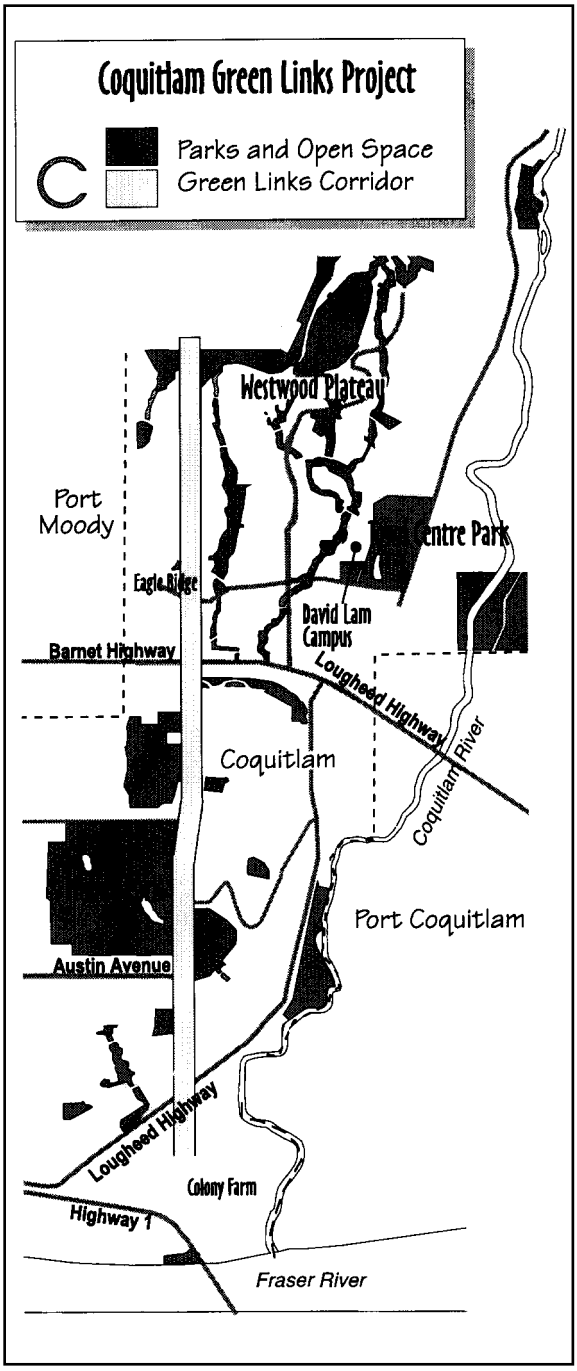

Figure 2. The 8km-long utility corridor in Coquitlam, British Columbia, used as the first Green Link Project demonstration site. The patches of green space it connects are shaded.

The Coquitlam BC Hydro/BC Gas right-of-way corridor was the first site to become part of Green Links in 1996 (Figure 2). The Coquitlam corridor is approximately 5 km long, 100 m wide and 128 ha in area. The land is primarily owned by the city. BC Hydro and BC Gas have been partners in the project since its beginning, assisting with funding, planning and operations. Within Coquitlam, Green Links increases connectivity between five ecosystem fragments:

Colony Farm (65 ha)—a habitat of field and marsh adjacent to the Coquitlam River, was recently made into a Greater Vancouver Regional District Park in recognition of its natural value.

Riverview Lands (31 ha) —which posses an ecologically unique arboretum stewarded by the Riverview Horticultural Society. The variety of trees it contains includes every tree species known to grow in British Columbia.

Mundy Park (192 ha) —a large municipal park containing a remnant forest and small lake with bog habitat. It is on the top of a moraine marking the boundary between the Burrard Inlet and Fraser River watersheds.

Pinnacle Creek ravine (59 ha) —part of the Chine Heights escarpment running between Coquitlam and Port Moody.

Scott Creek ravine (8.5 ha) —part of the Westwood Plateau and an important urban salmon stream of the Coquitlam River watershed.

The initial step in Green Links was to consult with the numerous community groups in the three project areas. Each were given a presentation on the project and in return provided a letter of endorsement. They later served on Advisory Committees for the project and volunteered for planting events. Community involvement was further cultivated through a community survey to gauge the level of support for green space enhancements. A design charette was also held for a Burnaby Link along a major through street in a residential neighbourhood.

Funding came from utility companies—BC Gas and BC Hydro, banks with community environmental grants—TD Canada Trust and VanCity Credit Union, gardening supply shops, and others. Government support was in the form of youth employment and environmental programs.

Plant stock was either purchased from wholesale nurseries or salvaged from development sites. Only native plants were used, and primarily low growing perennials and shrubs because of height concerns in electrical utility corridors (Figure 3). Some site preparation and much of the trail construction was done by the City of Coquitlam.

In addition to planting, land acquisition, restrictive covenants and other opportunistic tools will be pursued in the future to secure nodes of habitat to anchor the links.

Changes in community values were addressed through workshops, public speaking engagements, contests, murals, articles in newsletters and magazines, television and radio, and educational materials.

Results

Baseline biophysical inventories were completed for 14 sites along the Coquitlam corridor (Schaefer and Sulek 1997). The utility corridor supports 121 species of plants and 51 species of birds. The Simpson's biodiversity index for birds

Figure 3. Before and after photographs of a shrub community in the Surrey-Delta corridor established in a hydro right-of-way. The after shot is four years later.

from the 14 sampling sites along the 8 km corridor (Figure 2) ranges from 7.4-16.74, with an average of 10.7. Based on the biodiversity index of 13.0 found at a site second closest to the wilderness fringe of the corridor, a target was set to increase the average biodiversity index for the entire corridor to 13.0 over a 10-year period.

A community survey of 2,300 households in Coquitlam resulted in 327 respondents, the majority of which appreciated the green spaces in their community and supported habitat enhancement work.

In all, the Institute has restored habitat in the Greater Vancouver region at about 30 sites with 50,000 trees, shrubs and perennials (to create forests, woodlands and hedgerows), and sowed hundreds of pounds of seeds (to create meadows and old field habitat). This has been done with over 5,000 community participants and has been supported with an environmental education program involving over 12,000 workshop participants and 2,500 people attending our lectures and symposia. Our research has highlighted the value of backyard habitat, special places (cemeteries, golf courses) and utility corridors. All of our activities have generated about 150 newspaper and magazine articles, plus some radio and television appearances, that help to raise awareness of nature in the city.

Challenges

Lack of Topsoil and Water

Disturbed sites in a city are frequently devoid of topsoil. Also, drainage patterns are drastically altered to keep the ground dry for housing. Topsoil must often be added to, which is expensive and adds logistical problems to bringing heavy trucks onto the site. Watering adds maintenance time and labour. Impervious surface through rooftops and blacktop create wide swings of moisture availability, alternating floods with droughts that can destabilize existing plant communities.

Community Priorities
The restoration sites exist in a community context and there is resistance to changing the status quo. Restored areas are viewed as "conservation areas", so developers in the area fear that this will restrict their future development options. Homeowners fear that the restoration will attract more recreational users, bringing more people traffic. The educational activities of Green Links, as well as the Backyard Habitat Enhancement Challenge (recently changed in name to Nature's Havens), Gardens of Babylon Balcony Challenge, writing contests and photography contests are all aimed at fostering the value changes that make the restoration work acceptable.

Indicator Species
Green Links seeks to improve wildlife habitat, adding more natural value than was originally present before the project. However, it is important to have targets—what species are supposed to benefit? The connectivity analysis itself requires a weighting factor which is determined by the size of the habitat for the desired indicator species. Should this be a pleated woodpecker with a requirement of 10 ha, or something smaller such as a bush it or black-capped chickadee. This question is still unanswered.

The Urban Fabric
Wildlife habitat in the city is difficult to assess (see Schaefer et al. 2002). The fragments or "patches" offer different habitat quality to different species depending about their sensitivity to patch size patch shape, isolation and other characteristics. There is a complex interplay between species who are variously urban adapters, urban exploiters and urban avoiders. There are effect distances from roads that through noise and light pollution can influence the distribution and abundance of animals. These are in turn affected by road density, the volume of traffic and vehicle speed. Connectivity is one solution to habitat fragmentation but its benefits may be overwhelmed by the negative impacts of the many other disturbances to urban ecosystems.

Discussion
Both the theory of island biogeography and metapopulation dynamics assume that suitable patches of habitat are interspersed with uninhabitable areas (Andren 1994). The city is such a divided landscape. Therefore, it is important to remember that preserving green space in parks and other protected areas is only part of the solution. Without connections between them isolation and loss of genetic diversity is imminent. Green corridors, utility right-of-ways, hedgerows and backyard habitat are important parts of urban planning as they increase biodiversity in cities and improve the quality of life for all residents.
In many urban communities there is usually one large green space or mother node in a metapopulation zone that has significant influence on the surrounding area (in the Coquitlam corridor example presented here this would be Mundy Park). As the demand for land to develop grows with the population, cities can usually only afford to preserve a few large green spaces. These green spaces tend to have high biodiversity and provide important breeding and seeding habitat for interior species as well as edge species and transients. Around Mundy Park in Coquitlam, smaller green spaces or satellite nodes range in size from 0.1 hectare to over 100 hectares.

Many of satellite nodes may not be able support large numbers of species on their own but are able to provide important peripheral habitat to species in the mother node (Hansson 1991). Satellite nodes are partly or entirely dependent on individuals immigrating from the mother node (Hansson 1991). They have a higher rate of extinction than the mother nodes and therefore, need to be repopulated constantly (van Apeldoorn, et al. 1992). This requires proximity to the mother node. As the urban environment becomes increasingly densified and expands and fragments green space in the process, satellite nodes are getting smaller and further away from the mother node making dispersal even more difficult. As a way of preserving the biological integrity of a landscape, corridors and habitat matrices must be in place to allow dispersal between green spaces.

Our example of Mundy Park has a variety of different habitat types: wetland, coniferous forests, deciduous forests, and fields. As the satellite nodes also vary in their habitat types, the variety of flora and fauna in each of Mundy Park's habitat types are also able to use the different satellite nodes to the fullest extent. The corridor allows for dispersal between Mundy Park and the other nodes. A better situation is to have more corridors in a complex network (Rudd et al. 2002). More links equal more routes to suitable habitat creating more opportunities for dispersal. This is important because suitable habitat often remains unused as it becomes isolated (Hanski and Thomas 1994).

An important component of network planning is the consideration of private and unprotected areas. Backyard habitat can be an invaluable food and habitat source for a wide range of urban species and is essential in developing the matrix, which supports the large numbers of corridors required for connectivity. Public education on gardening with native plants

and providing proper habitat is another tool to enhance the connectivity of the region and improve the viability of the corridors. This is crucial in urban areas because of existing development and lack of green space.

Green Links will allow for the greater use, movement, dispersal and interaction of plants and animals between more significant areas of urban wildlife habitat. The stronger the connection, the greater the ecological value of the habitat. This should result in an increase of biodiversity to higher levels found in the area.

Although the benefits of connectivity are well documented in wilderness areas, its benefits to ecological restoration in urban areas are still unclear. Green Links is attempting to establish connectivity and determine its value in an urban context.

References

Andren, H. 1994. Effect of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos. 71: 355-366.

van Apeldoorn, R.C., W.T. Oostenbrink, A. van Winden, and F.F. van der Zee. 1992. Effects of habitat fragmentation on the bank vole, *Clethrionomys glareolus*, in an agricultural landscape. Oikos. 65: 265-274.

Brown, L., Flavin, C., and S. Postel. 1991. Vision of a sustainable world. In. Bron, L. (Ed.). The Worldwatch Reader on Global Environmental Issues. Norton, New York.

Dmowski, K. and M. Kozakiewicz. 1990. Influence of a shrub corridor on movements of passerine birds to a lake littoral zone. Landscape Ecology 4:99-108.

Environment Canada.1993. Environmental Citizenship - The Nature of Canada: A Primer on Spaces and Species. Ottawa.

Environment Canada and BC Ministry of Environment, Lands and Parks. 1995. Naturescape BC. Victoria.

Environment Canada and BC Ministry of Environment, Lands and Parks. 1996. Community Greenways. Victoria.

Greater Vancouver Regional District. 1995. Livable Region Strategic Plan. Burnaby, BC.

Hanski, I. and C.D.Thomas. 1994. Metapopulation dynamics and conservation: a spatially explicit model applied to butterflies. Biological Conservation. 68: 167-180.

Hansson, L. 1991. Dispersal and connectivity in metapopulations. Biological Journal of the Linnean Society. 42: 89-103.

Harris, L. 1984. The Fragmented Forest. University of Chicago Press, Chicago.

Healey, M.C. 1997. Prospects for Sustainability: Integrative Approaches to Sustaining the Ecosystem Function of the Lower Fraser Basin. Westwater Research Centre and the Sustainable Development Research Institute of the University of British Columbia, Vancouver, BC.

Henein, K. and G. Merriam. 1990. The elements of connectivity where corridor quality is variable. Landscape Ecology 4: 157-170.

Linehan, J., Gross, M. and J. Finn. Greenway planning: developing a landscape ecological network approach. 1995. Landscape and Urban Planning (33): 179-193.

MacArthur, R.H. and E.O. Wilson. 1967. The Theory of Island Biogeography. Princeton University Press, Princeton.

Noss, R.F. 1987. Corridors in real landscapes: a reply to Simberloff and Cox. Conserv. Biol.: 159-164.

Opdam, P. 1991. Metapopulation theory and habitat fragmentation. Landscape Ecol. 5: 93-106.

Rudd, H., Vala, J. and V. Schaefer. 2002. Importance of backyard habitat in a comprehensive biodiversity conservation strategy: a connectivity analysis of urban green spaces. Restoration Ecology 10(2):368-375.

Schaefer, V., Rudd, H. and J. Vala. 2002. Urban Biodiversity: Exploring Natural Habitat and its Value in Cities. Douglas College Centre for Environmental Studies and Urban Ecology, New Westminster, BC 149 pp.

Schaefer, V.H. and M. Sulek. 1997. Green Links: Connecting Ecosystem Fragments in the City. Volume 1: Coquitlam Demonstration Project. Douglas College, New Westminster, BC.

Schaefer, V.H. 1994. Urban Biodiversity. In: Biodiversity in British Columbia. Harding, L. and E. McCullum (Eds.). pp. 307-318. Environment Canada.

Schaefer, V.H., Aston, M., Bergstresser, N., Gray, J. and P. Malacarne. 1992. Urban Ravines. Vol. 1. Byrne Creek - A Case Study. Vol. 2. B.C. LowerMainland Urban Ravines Inventory. Douglas College Institute of Urban Ecology, New Westminster, BC. 452 pp.

Searns, R.M. 1995. The evolution of greenways as an adaptive urban landscape form. Landscape and Urban Planning (33): 65-80.

Simberloff, D. and J. Cox. 1987. Consequences and costs of conservation corridors. Conserv. Biol.: 63-71.

Smith, D. and P.C. Hellmund. 1993. Ecology of Greenways: Design and Function of Linear Conservation Areas. University of Minnesota Press, Minneapolis.

Thorne, J.T. 1993. Landscape Ecology. In: Smith, D. and P.C. Hellmund. Ecology of Greenways: Design and Function of Linear Conservation Areas. University of Minnesota Press, Minneapolis.

Wegner, J.F. and G. Merriam. 1979. Movements of birds and mammals between wood and adjoining farmland habitat. J. Applied Ecology 16:349-357.

Wilcox, B.A. and D.D. Murphy. 1985. Conservation strategy: the effects of fragmentation on extinction. Am. Nat. 125: 879-887.