CHAPTER 20

Ecological Demography

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Hauser and Duncan's *The Study of Population* (1959) contains two chapters dealing with the interplay of ecology and demography. One is written by the biologist Peter W. Frank and the other by the demographer Otis Dudley Duncan. Frank's chapter draws on the principles of general ecology (referred to in his chapter as *population ecology*[1]) and shows their application to natality, mortality, age distribution, density, and several other demographic topics. Frank's examples are applied to *Homo sapiens* and to a variety of other species, such as Norway rats, fruit flies, butterflies, locusts, cockroaches, water fleas, and Pacific mackerels. Duncan's chapter argues that human ecology, in contrast to general ecology, provides a general "perspective, heuristic principles and concepts, and specific hypotheses of first-rate significance to the demographer" (1959: 678).

Duncan (1959) also provides one of the first theoretical expositions of the *ecological complex*, that is, the "collection of analytically distinguishable elements [of population, organization, environment, and technology], whose identification is part of the task of ecological theory" (1959: 684). In the literature of human ecology, Duncan's chapter is central and is one of the most cited theoretical treatments of the subject matter (for a recent review, discussion, and elaboration of the ecological complex, see Micklin and Sly [1998]).

This chapter is more consistent with Duncan's perspective than with Frank's, although it is narrower in orientation. It draws on human ecological theory as developed

[1] Frank's use of the term population ecology is different from that of Carroll and Khessina in this *Handbook*.

by Hawley (1950, 1968, 1986, 1998), Duncan (1959, 1961, 1964), Gibbs and Martin (1959), Schnore (1958, 1961), Namboodiri (1988, 1994), and several others (Micklin [1973], Poston et al. [1984], Micklin and Poston [1998], Micklin and Sly [1998], and Poston and Frisbie [1998]) and shows its relevance and application in analyses of the demographic processes of fertility, mortality, and migration.

Duncan notes that a difficulty in discussing the perspective of human ecology is that "even a provisional statement of [its] concerns will doubtless encounter strong objections from one or another group of scientists and thinkers who regard their studies of man as exemplifying the ecological viewpoint" (1959: 679). The next section of this chapter thus presents definitions of human ecology and ecological demography as the terms will be used in this chapter. A later section draws on current and past literature and illustrates the application of human ecology in the study of the demographic processes.

WHAT IS HUMAN ECOLOGY? WHAT IS ECOLOGICAL DEMOGRAPHY?

Human Ecology

Ecology may be defined as the "study of the interrelationships of organisms with their environment and each other" (*Encyclopedia Britannica* 1988: 959). One of the first statements was that of the Greek philosopher Theophrastus, who studied the "interrelationships between organisms and between organisms and their nonliving environment" (*Encyclopedia Britannica* 1988: 959). Ernest Haeckel used the term ecology in his study of plants, which was published in 1868. The term made its way into the English language with the translation of Haeckel's book in 1876. The term *human ecology* was first used by Robert Park and Ernest Burgess in their *Introduction to the Science of Sociology* (1924). For the first several decades after the term was introduced to sociologists, there was little agreement about its meaning and focus (Alihan 1938; Gettys 1940; Firey 1945). Amos Hawley's book, *Human Ecology: A Theory of Community Structure* (1950), which to this day is the definitive exposition of the field, sets out the subject matter of human ecology and its approach. According to Hawley, human ecology deals with "how growing, multiplying beings maintain themselves in a constantly changing but ever restricted environment" (1950: 66). For human populations, this requires examining the ways in which individuals act collectively to achieve more effective use of their habitat.

Despite this clear and unambiguous statement, some scholars ascribe to human ecology perspectives that are inconsistent with Hawley's thinking and that of McKenzie (1924, 1934, 1968), his predecessor and teacher. Three examples will suffice.

First, the sociobiologist Pierre van den Berghe notes that "sociologists who claim to be ecologists … have reduced this specialty to a pedestrian kind of social geography (where) they largely plot social characteristics of people on maps" (1990: 174). Second, sociologists John Logan and Harvey Molotch write that "in human ecology, spatial relations are the analytical basis for understanding urban systems" (1987: 4). And, third, the social theorist Manuel Castells discusses the parallels between Marxian and ecological thinking and observes that the results obtained by ecology have no more value for establishing a theory of space than a mass of sociocultural correlations (1979: 122–123). Not only is Castells' comment incorrect, it also fails to capture the important materialistic and organizational similarities and differences between Marxist and ecological theory (for a statement, see Hawley [1984]).

These characterizations of human ecology as merely the study of spatial relations are due in part to the unfortunate statement of McKenzie (1924) in which he defined human ecology as the "study of the spatial and temporal relations of human beings as effected by the selective, distributive and accommodative forces of the environment." Hawley notes that although this simple, lucid statement inspired a great amount of empirical investigation, it caused human ecology to be regarded as little more than a descriptive study of spatial distributions, an outcome that McKenzie later noted was a misplacement of emphasis. Attention to spatial patterns, McKenzie recorded in his notes, should be subordinate and incidental to the analysis of sustenance relations (see Hawley's remarks in McKenzie [1968: xiii–xiv]).

There are other examples of the misuse or misunderstanding by social scientists of human ecology. Some refer to human ecology as studies using spatial rather than individual units of analysis (Robinson 1950), or as analyses of the physical features of geographical and built-up areas (Zorbaugh 1929; Suttles 1972), or as the factor analyses of the characteristics of aggregate units, i.e., factorial ecology (Berry and Rees 1969).

These illustrations exemplify Duncan's observation that "the term ecology is sometimes applied rather casually – even irresponsibly. [Frequently] studies adopting the label bear only a tenuous relationship to any systematic, scientific conception of the field" (1959: 680).

Human ecology is a field of study grounded in the four referential constructs of population, technology, organization, and environment. The unit of analysis is the human population, circumscribed more or less in a territorial fashion. Its major assumptions are that populations have unit character and integrity and that properties and attributes of these populations are more than the summation of their component parts.

Human ecology is concerned with the organizational aspects of human populations that arise from their sustenance-producing activities. These activities are necessary for the collective existence of the populations and must be adapted to the changing conditions confronting them. Included are an ever changing and mediating environment, their technological repertoires, and the size, composition, and distribution of the populations themselves (Duncan 1959; Frisbie and Poston 1975, 1978a, 1978b; Poston 1980, 1981).

Human ecologists address questions such as: What are the structural arrangements that characterize a population's sustenance-related endeavors? Under what conditions does one form of sustenance structure appear rather than another? What are the consequences for populations of varying configurations of sustenance-producing activities?

The answers lie in the fact that populations survive by virtue of collective organization. Human ecology is concerned with the determinants and consequences of sustenance organization, a consideration that addresses the interplay between human ecology and demography.

Much of the empirical literature of human ecology in recent decades focuses on demographic applications. The next section outlines the focus of ecological demography.

Ecological Demography

Human ecology offers demography an aggregate perspective for the analysis of the demographic processes. A fundamental tenet of human ecology is that a population redistributes itself through the vital processes and migration to achieve a balance or equilibrium between its size and life chances (Hawley 1968: 331; also see Davis [1963]). Duncan (1959: 708) also emphasizes the important ecological connections between organization and population size. Hawley (1950) notes that human populations will adjust their size through any of the demographic processes to maintain an equilibrium with their sustenance organization. Stated in another way, "demographic structure contains the possibilities and sets the limits of organized group life" (Hawley 1950: 78; see also Poston [1983]). Ecological demography is the application of human ecological theory to the analysis of the demographic processes.[2]

Although ecological theory provides an approach for the investigation of any of the three demographic processes, it is shown below that most empirical research has focused on population change due to net migration. The next section reviews major research in ecological demography.

ECOLOGICAL DEMOGRAPHY AND THE DEMOGRAPHIC PROCESSES

A principal theme in the human ecological literature since the publication of Hawley's *Human Ecology* (1950) is the relationship between changes in ecological and sustenance organization and the demographic processes. This owes to the already mentioned tenet of human ecology that populations redistribute themselves through fertility, mortality, and migration to maintain an equilibrium between size and opportunities for living. A basic premise is that a moving equilibrium is maintained between a population's size and the resource base from which its sustenance is drawn. The level at which a population survives is a function of this balance. According to Hawley, it is "the ratio of numbers to the opportunities for living" (1950: 149).

One thus arrives at the proposition that there is a reciprocal relationship between population size and organization for sustenance that operates through the influence of each on a population's level of living. Treating population size as dependent and sustenance organization as independent leads to the hypothesis that change in sustenance organization, to the extent that it produces change in the opportunities for living, will necessitate a change in population size. Analyses that have focused on this relationship are reviewed in this section, according to each of the three processes.

Ecological Analysis of Migration

As noted, of the three demographic processes, migration is the most efficient agent for effecting change in population size. The hypothesis often investigated in ecological studies of this genre is that variation among populations in levels of net migration is a function of differentials in sustenance organization. As particular sustenance functions in a population expand, new positions or niches are created; these niches are typically job opportunities, although other features of sustenance organization may be

[2] Namboodiri (1988) defines ecological demography somewhat more broadly. There is another subarea referred to as ecological demography that follows evolutionary and anthropological perspectives. For a discussion of this subject matter see Clark and Low (1991) and Low et al. (1992).

considered. Conversely, the diminution of certain sustenance functions results in a contraction of the number of niches and, hence, a reduction in the opportunities for employment. The net result of these developments, unless the effects of one cancel out those of the other, is a disturbance in the established equilibrium between population size and opportunities for living. Net migration is thus viewed as a population response, or as an effective method of returning to a condition of balance. Hawley writes that ''readjustments to disequilibrium are effected primarily . . . through mobility. Population tends to distribute itself in relation to job opportunities, evacuating areas of diminishing opportunities and gravitating to areas of increasing opportunities'' (1950: 167–168).

The ecological model is explicitly macrolevel. Ecological models of migration endeavor to recognize the characteristics of aggregates, such as countries or states/provinces, that lead to the net gain or loss of population through migration. Whereas microlevel analyses ask ''Who moves and why?'' ecological analyses ask ''Where do migrants go and why?'' Microlevel variables such as attitudes and motives do not play a role in ecological models. Psychological factors may have some effect on decisions to move, but a neglect of structural variables in order to concentrate on psychological variables overlooks the fact that attitudes and values are themselves components of behavior ''and as such, should be explained rather than be used as the explanation'' (Sly 1972: 616; see also Frisbie and Poston 1978b: 9). In this regard Hawley (1950: 320) writes:

> No doubt migration involves psychological elements, but it is also a manifestation of external changes. For an understanding of the general phenomenon, it is important to know not why the migrant thinks he has moved, but the conditions or characteristics common to all instances of migration and lacking in situations from which there is no migration.

An early test of this relationship is Sly's (1972) study of southern black migration from the ''old cotton belt,'' a group of some 253 counties (with at least 25,000 acres in cotton as reported in the 1890 census) stretching in a belt from South Carolina to Texas. Migration patterns were hypothesized as responses to changes in organization, as well as in technology and the environment. Sly's ecological hypothesis was tested with data on southern black migration for the decades 1940 to 1950 and 1950 to 1960, and support was adduced for the ecological model.

Frisbie and Poston (1975) expanded on these results by noting that while there may be an overall relationship between sustenance organization and demographic behavior, the relationships will differ, depending on the particular kind of substance activity examined. They specified eight different components of sustenance organization for the nonmetropolitan counties of the U.S. in the circa-1960 time period. They hypothesized that ''areas heavily dependent upon primary industry such as mining or agriculture (with the possible exception of large-scale agriculture) are likely to be population-decline areas; areas where services constitute the most significant form of sustenance activity are likely to be characterized by growing populations; areas dependent on transformation industry are expected to be intermediate in terms of growth potential'' (1975: 776). Their hypotheses were upheld.

In a follow-up analysis, Frisbie and Poston (1976) hypothesized that the sustenance organizations of areas experiencing population growth in the 1960s should be more complex (that is, be characterized by more sustenance functions) than those experiencing population loss. As predicted, sustenance configurations for the growing counties were found to be more complex that those for the losing counties.

In two additional investigations that supported the ecological model, Frisbie and Poston (1978a, 1978b) investigated the relationships among sustenance organization components, sustenance differentiation, and the net migration behavior of the nonmetropolitan counties of the U.S. in the 1960 to 1970 period (see also Hirschl, Poston, and Frisbie [1998]).

Poston and White (1978) extended the above analyses by introducing a variable that mediates the association between sustenance organization and population/migration change, namely, the potential supply of labor in the population, that is, the indigenous labor force supply (see also, Pursell 1972; Bradshaw 1976; Bowles 1976). It turns out that the effect of indigenous labor force supply on migration is independent of the effects of other aspects of sustenance organization (see also Ervin [1987]).

The studies cited are but a selection of numerous investigations that have examined the extent to which migration appears to be a demographic response to changes in ecological and economic organization (cf., Gibbs 1964; Stinner and DeJong 1969; Tarver 1972; Brown 1975; 1998; 2002; Beale 1975; Fuguitt and Beale 1976; Sly and Tayman 1977; Wardwell 1977; Shin 1979; Krout 1982; London 1986, 1987; Ervin 1987; Saenz and Colberg 1988; Poston, Hirschl, and Frisbie 1991).

Ecological Analyses of Fertility and Mortality

Less prominent among human ecological studies of demographic behavior are investigations that focus on fertility and mortality. This section examines this limited literature.

An ecological explanation of fertility behavior focuses on the sustenance organization of human populations and ascertains the extent to which differences in their organizational forms and structures are related to differences in their fertility behavior.

One way of viewing this relationship involves thinking of fertility behavior as a means of increasing or decreasing the size of the population in much the same way as migration. To illustrate, the population's sustenance organization could become more complex and new positions would be created. The population would need to respond demographically and provide members to fill these niches, so that the initial equilibrium between population size and organization could be maintained.

Fertility behavior is not the most efficient demographic response because of the time lag between the creation of the new members and their eventual employment in sustenance activities. Sly writes that in the "short run, migration appears to be the most efficient response. It can increase (or decrease) population more rapidly than can changing fertility and is more efficient in that it can be more selective" (1972: 618).

It is likely that sustenance organization complexity influences fertility behavior in a different way than that just discussed. Rather than the two being related positively, they are related negatively. In the first place a high fertility pattern is dysfunctional for an increasingly complex sustenance organization because so much of the sustenance produced must be consumed directly by the population. High fertility should reduce the absolute amount of uncommitted sustenance resources, thereby limiting the population's flexibility for adapting to environmental, technological, and other kinds of changes and fluctuations. Low fertility is more consonant with the needs and requirements of an expansive sustenance organization. More sustenance would be available for investment back into the system in a low-fertility population than in a population with high fertility. Large quantities of sustenance normally consumed by the familial and educational institutions in a high-fertility population would hence be available as mobile or fluid resources in a low-fertility population. Sustenance organization in this latter instance would thus have the investment resources available for increasing complexity, given requisite changes in the environment and technology. One would thus hypothesize a negative relation between organizational complexity and fertility.

An early ecological study of fertility is Kasarda's (1971) comparative analysis of nations between 1930 and 1969. Reasoning that the level of fertility in a society should be associated with its type of sustenance organization, he investigated the degree to which female labor force participation in nonagricultural occupations, the number of unpaid family workers, and the degree of youth labor force participation served as intervening variables between the less proximate effects of industrialization, urbanization, and education. His findings suggest that most of the intervening variables are associated with fertility. Moreover, with regard to the ecological theory of fertility, he shows that the less proximate factors affect fertility through the intermediate variables (1971: 314).

In a later ecological study of fertility, London (1987) focuses on the explicitly human ecological aspects of economic development and their influences on fertility. He examines the relationship between measures of the division of labor (Gibbs and Poston 1975) and the crude birth rate among the provinces of Thailand for the 1960 to 1970 period. He hypothesizes that the greater the complexity of the division of labor, the lower the fertility. At the bivariate level he finds support for his hypothesis.

In an extension of the above analysis, London and Hadden (1989) examine the utility of three different fertility theories, namely, human ecological theory, "wealth flows" theory, and political economic theory, as explanations of fertility differentials among the provinces of Thailand. They find that "hypotheses derived from [these] three different theoretical perspectives received support ... [suggesting] that no existing 'theory' by itself can fully explain a phenomenon as complex as fertility decline" (1989: 34).

Poston and Chang (2005) use an ecological model and other theoretical perspectives in their study of female and male fertility rates among the counties of Taiwan in 1995. Their ecological model focuses on ecological organization; they reason that the more complex the organization, the lower the fertility. The ecological model works as expected in explaining variation in female fertility rates but does not do as well in accounting for male fertility differences among the counties.

A review of the literature of ecological demography finds several analyses of mortality (for example, Gibbs 1959; Davis 1963; Friedlander 1969). The study by Gibbs (1959) of the relationship between changes in mortality and fertility and changes in sustenance organization is representative of this genre. He is interested in ascertaining whether human populations avoid an increase in mortality by reducing their fertility when confronted with organizational changes leading to decreases in sustenance. He examines changes in the crude death and birth rates for 45 countries circa 1921 to 1937 (the years of worldwide economic depression). His expectations are generally supported by the data.

Having reviewed relevant literature in ecological demography, the next section focuses explicitly on migration and endeavors to illustrate how demographic studies of internal migration can be theoretically informed by the rubrics of the ecological complex: organization, population, technology, and environment. Each of the rubrics is discussed separately.

FOUR HUMAN ECOLOGICAL CONCEPTS AND THE ANALYSIS OF MIGRATION

This section[3] discusses the conceptual and theoretical development of the four rubrics of the ecological system and proposes the kinds of relationships anticipated between each and population change due to internal migration.

Organization

It is not an overstatement to say that organization is the fundamental element of the subject matter of human ecology. This is so because it is social organization that mediates the balance between population size, growth, and distribution and the natural environment upon which it depends (Micklin 1973). Human ecology is concerned with the organizational aspects of human populations arising from their sustenance-producing activities (Frisbie and Poston 1978b: 14). In fact, the two broad goals of human ecology are to establish (1) the causes and (2) the consequences of particular characteristics of sustenance organization in human populations (Gibbs and Martin 1959: 33). The latter goal is of particular importance in ecological analyses of migration.

There is major agreement regarding the centrality of organization within human ecology (Duncan 1959; Hawley 1950; Gibbs and Martin 1959; Micklin 1973; Poston, Frisbie and Micklin 1984; Namboodiri 1994; Poston and Frisbie 1998). However, despite its central position in human ecology and in the ecological theory of migration, the idea of sustenance organization was for decades in a primitive state of development both conceptually and empirically. Indeed, most of the research on sustenance organization that ecologists conducted in the 1950s and 1960s treats the concept as if it referred solely to the division of labor. This occurs even though there is little in the extant theoretical treatments of the concept to warrant such a limitation.

The notion of organization in human ecology is multifaceted. Attention here will thus be directed to some of the characteristics of sustenance organization and will suggest their relationships with migration. A major dimension of sustenance organization involves what Hawley refers to as the "arrangement of differentiated parts suited to the performance of a given function or set of functions" (1950: 178). This is sustenance differentiation, i.e., the extent to which the population is differentiated in its sustenance activity.

Sustenance differentiation consists of two elements: (1) the number of activities and (2) the degree of uniformity in the distribution of the population across the activities. A high degree of sustenance differentiation obtains when there is a relatively large number of activities characterizing the population and when the population members are evenly distributed across these activities (Gibbs and Poston 1975). Scholars since Durkheim (1893 [1960]) have included this dimension as a major component of the division of labor. There are many measures of sustenance differentiation, six of which have been elaborated by Gibbs and Poston (1975).

A positive relationship is expected to obtain between sustenance differentiation and migration. Increases in sustenance differentiation should result in an expansion in the

[3] This section draws in part on materials in Poston and Frisbie (1998).

number of ecological niches, so that the original balance between population size and life chances must be reestablished, with net in-migration serving as the most efficient mechanism. One would hypothesize that the greater the degree of sustenance differentiation, the greater the population growth attributable to migration.

Another dimension of sustenance organization is functional interdependence; it can be combined with sustenance differentiation to form the other side of the division of labor (Gibbs and Poston 1975). The degree of functional interdependence in a population depends on (1) the number of exchange linkages, (2) the variety of products involved, and (3) the volume of exchange flows (Eberstein and Frisbie 1982). Empirical indicators of functional interdependence are often based on commodity-flow data. It is reasonable to assume that the greater the degree of involvement of an area in the society-wide web of interdependence, the more that area will be a major point of confluence for goods, services, and financial resources, all of which should lead to an expansion of the population via migration.

A third dimension of sustenance organization is the volume of sustenance produced by the population, i.e., the degree of productivity of the particular configuration of sustenance activities. Research on U.S. migration patterns (Poston and Frisbie 1984) uses data from the censuses of business and agriculture to tap five aspects of sustenance productivity: retail services productivity, wholesale services productivity, personal services productivity, agricultural productivity, and mining productivity. How should each component be related to net migration? Although these are only five examples of a larger number of components of sustenance organization, discussion of them and their linkages with migration illustrates the applicability of sustenance components in ecological analyses of migration.

It may be hypothesized that productivity in retail services is positively related to migration, because growth in retail services is often linked closely to employment growth and associated economic opportunities. Consequently, areas that are highly productive of retail sustenance should be characterized by in-migration. In contrast, areas with significant amounts of wholesale sustenance productivity are expected to have more out-migration than in-migration, because increases in wholesale volume need not necessarily be associated with increases in employment in wholesaling. Frisbie and Poston (1978b: 50) write that "wholesalers may be able to absorb expanding business by the addition of a comparatively few employees, accompanied by a much greater degree of mechanization."

Similarly, areas high in personal services productivity should be characterized more by net losses due to migration. Included among personal services are amusement and recreation services and hotel and motel employment. Services that support recreation and leisure time activities may be linked to economic opportunities, especially in areas that offer amenities such as a mild climate (Kasarda 1980). However, personal services occupations are often low-paying, so there is no necessary reason to expect a positive effect on migration (Poston 1981: 146).

A positive relationship should exist, however, between agricultural productivity and migration. Agricultural productivity is usually measured as the dollar amount of agricultural products marketed per farm with sales above a particular amount, say, $10,000 or $25,000. Accordingly, areas "in which commercial agriculture is pursued successfully [can be expected to] enjoy an expansion of job opportunities [and positive net migration] as a complex of ancillary agribusiness establishments develops" (Frisbie and Poston 1978b: 48–49). Therefore, unlike the frequently demonstrated negative relationship between small-scale agricultural activity and net migration, in this case one would expect a positive association.

The last sustenance productivity variable is mining. A negative association is expected with net migration because of the reduced demand for labor in an extractive industry such as mining (which typically comprises metal, bituminous coal, and lignite mining, as well as oil and gas extraction), once such areas are past the initial exploration and "boom" stage (Frisbie and Poston 1978b: 46).

A fourth dimension of sustenance organization is the degree of efficiency of the sustenance organization. Given the level of sustenance produced, how efficiently does this occur? How much effort is required to produce the sustenance, whatever its volume? Ideally, such a variable would be operationalized by developing a ratio of the amount of sustenance produced to the amount of energy consumed in the production process. Unfortunately, data of this type are not available below the national level. In earlier research Poston and Frisbie (1984) examined the efficiency of the manufacturing component, operationalized as the value added by manufacturing per manufacturing establishment. The numerator reflects the dollar value of the shipments after accounting for the manufacturing inputs. As conceptualized and operationalized, manufacturing efficiency is more capital intensive than labor intensive. Almost by definition, the greater the efficiency, the less the requirement for personnel inputs. Accordingly, one would hypothesize that the relationship between manufacturing efficiency and net migration is inverse.

A final structural characteristic or dimension of sustenance organization is the degree to which population members are engaged in sustenance-related pursuits (Poston and Johnson 1971; Martin and Poston 1972, 1976). What patterns of utilization of population members characterize the organization of one ecological unit versus another, especially with regard to ascribed statuses? How fully realized are the potential contributions of population members? To what extent do inequalities exist in the population by ascribed statuses? The degree to which populations differentiate by ascribed statuses in allocating sustenance roles to their members is an important dimension of sustenance organization, especially if the analyst is interested in sustenance productivity and other input-related functions.

To some extent, differentiation by ascribed, rather than achieved, status may have a direct effect on the likelihood of an area's gain or loss due to net migration. This is most likely when the focus is on race- or sex-specific migration, because if issues of ascribed status significantly affect the distribution of workers across employment categories, they may act as a deterrent to the in-movement of minorities and females. On a more general level, if an unreasonable reliance on ascribed status as an allocative mechanism undermines the most productive use of labor, sustenance productivity will be negatively affected, which, in turn, will inhibit movement into the area. Conversely, in Saudi Arabia and other Middle Eastern countries, female labor is very limited and results in very heavy immigration of expatriate labor.

Population

It goes without saying that of the four ecological concepts, population is the most advanced in terms of conceptual and operational detail. This is easily understood since an entire specialization, demography, is devoted to the study of population characteristics and dynamics (see many of the chapters in this *Handbook*). However, with few exceptions (Poston and White 1978; Frisbie and Poston 1978b; Namboodiri 1994), ecologists seldom examine dimensions of the population as influences on population redistribution. Yet it is well known from demographic research that such population variables as age, race, and sex composition have predictable effects on net migration (see chapter 1, "Age and Sex," in this *Handbook*).

In an earlier section of this chapter, attention was directed to the research of Poston and White (1978) introducing the need to consider the size of the potential labor force already in the population as a mediating influence of the relationship between other ecological variables and migration.

In other research on nonmetropolitan migration, Frisbie and Poston (1978b) examine the extent to which demographic variables such as racial composition and age structure influence migration, despite the already demonstrated relationships between various components of sustenance organization and nonmetropolitan net migration. They suggest that if, "as seems to be the case from available evidence, blacks continue to leave nonmetropolitan areas where historically the minority was heavily concentrated, and if whites are not apt to move to these areas in numbers great enough to offset the loss of blacks, it would appear plausible to hypothesize an inverse relationship between percent nonwhite and net migration change" (Frisbie and Poston 1978b: 67). Regarding age structure, they note that numerous nonmetropolitan counties with many elderly residents grow through net migration. However, despite the prevalence of these "retirement" counties, they hypothesize that "one would expect a negative relationship between median age and net migration for no other reason than the fact that migration is selective of young adults" (Frisbie and Poston 1978b: 68). Their analyses supported both hypotheses.

Technology

Of the four basic ecological categories, technology is the most critical for the adaptation of human populations. Lenski (1970: 102–103) writes that technology is the "prime mover" in the process of social change and adaptation for at least three reasons: (1) it sets the boundaries for feasible social and economic options; (2) technological change appears to be more easily accepted by the population than change in organization or ideology; (3) it is "easier to compare the effects of alternative tools or techniques than it is to compare the effects of alternative systems of social organization or alternative ideologies" (Lenski 1970: 102).

The concept is prominent in ecological and other macrolevel sociological theories. And there is a consensus in definitions of technology. Frisbie and Clarke (1979:593) note the following:

> A fair degree of convergence is evident in efforts to theoretically circumscribe the concept. Lenski (1970: 37) defines technology as 'the information, techniques, and tools by means of which men utilize the material resources of their environment.' Similarly, Sjoberg (1965: 214) describes technology as 'the tools, the sources of energy and the knowledge connected with the use of both tools and energy that a social system employs.' On a slightly less abstract level and using somewhat different terminology, Ogburn (1955: 383) conceives of technology as the 'kinds of capital equipment, quantity of capital goods, manner and use of non-human resources, scientific discovery, invention (and) machines.' Finally, Duncan notes that the 'concept of

"technology" in human ecology refers not merely to a complex of art and artifact... but to a set of techniques employed by a population to gain sustenance from its environment and to facilitate the organization of sustenance-producing activity' (1959: 682).

Three dimensions figure prominently in the above definitions: material features (tools, capital equipment, machines); information (knowledge, techniques, scientific discovery); and energy. These are the same three ecosystem "commodity" flows that Duncan (1964) identifies as basic to the survival of populations. However, the problem with trying to apply these three dimensions to national subareas, such as counties, states, or provinces, is that, like the larger concept of technology of which these are a part, the dimensions have been conceived at the societal level of analysis. It is difficult to contend that the level of technology, as just defined, varies in any significant way at the subsocietal level. For example, not all county populations make use of the same tools, techniques, and information, but the technology available, while its actual application may be concentrated in a few areas, tends to have a society-wide impact in urban industrial nations. In a sense, then, the level of technology is a constant for population groups such as the counties, states, or provinces of countries. The fact that one county might differ from another in its energy consumption per capita, or in regard to some other measure of technology, is due not so much to differentials in levels of, or access to, technology, as from variations in climate, natural resources, and social organization that require or make feasible the application of given technologies. Thus, at the subsocietal level it is necessary to focus primarily on particular applications of technology that bear directly on the substantive question of interest, rather than on the level or availability of technology.

Scholars have given only minimal attention to the issue of empirically applying the technology component of the ecological complex to the study of populations below the societal level. As a consequence, there are few guidelines to suggest even a point of departure in specifying particular technological applications with significant consequences for migration patterns. An exception is the strategy followed by Sly (1972) in his study of black male migration from southern cotton-belt counties. In that research, Sly brings the technological dimension to bear in highly specific terms by incorporating into his analysis particular technological variables (viz., farm gasoline consumption and the use of tractors) that could be expected to have an impact on the particular population of interest. The implication is that in attempting to explain variations in migration among counties, it is necessary to narrow the focus to those specific technological factors that bear directly or indirectly on the ability of counties to attract population.

A first approximation toward conceptualization may be made by noting that one of the long-recognized technological keys to the establishment and growth of population aggregates is the presence and development of adequate transportation facilities. More than 100 years ago, Cooley (1894 [1930: 75–83]) observed that population and wealth will tend to come together wherever there is a break or an interruption in routes of transportation. The development of transportation facilities partially determines industrial concentration and influences the expansion of local populations (Hawley 1981). Since the availability of transportation is a major determinant of the ease of access of a population to its environment, a population's ability to compete with other populations, and the efficiency of sustenance extraction, the first dimension of technology to be considered should involve mobility facilitating technology.

Two empirical indicators of this dimension of technology are the presence of an interstate highway crossing a county (or state or province) and the intersection in the area of two or more interstate highways. While these measures may be "obvious," the obviousness of their influence does not imply either triviality or simplicity of effect. In fact, there is a large literature that testifies both to the importance and complexity of the impact of interstate arteries on subarea population change in general and change due to migration in particular (Dickinson 1964; Wheat 1969; Gauthier 1970; Fuguitt and Beale 1976; Briggs 1980; Lichter and Fuguitt 1980).

Although there is some disagreement regarding the actual magnitude of the effects of interstate highways on population redistribution and net migration, most theoretical discussions point to a positive relationship that may be indirect as well as direct. Briggs (1980) presents a rationale underlying the expectation of a relationship between the presence of interstate highway crossings and intersections and net migration. He finds that the interstate highway system facilitates the total amount of movement by lowering the time-cost of travel and "channels this movement along fewer paths" (1980: 22), thereby favoring those areas which lie at the intersection of these paths. One would also expect that major highways will have an indirect effect, because they "give impetus to fundamental changes in the sustenance organization or economic activity [especially] in non-metropolitan areas, resulting in a demographic response, namely, in-migration" (Lichter and Fuguitt 1980: 494). One reason for anticipating a positive effect on net migration is that interstate highway links stimulate local economies as services develop to serve travelers (Briggs 1980), as industry finds it possible to locate or expand in these more easily accessible places, and as local market expansion is facilitated (Lichter and Fuguitt 1980).

Research based on the theories of McKenzie, Hawley, and other ecologists shows that centrality in the airline network of the United States has effects that parallel those found with respect to interstate highways. Although not focusing specifically on net migration, the work of Irwin and Kasarda demonstrates that being a hub in the airline network is significantly related to employment growth in metropolitan areas, and "that changes in network position are a cause rather than a consequence of this employment growth" (Irwin and Kasarda 1991: 524).

A second kind of technological application deals with the acquisition of sustenance. At a minimum, ecologists need to develop indicators of this dimension that reflect technological inputs affecting both primary and transformative sustenance activities. One such set of indicators indexes those features of agricultural technology that previous research shows to affect county net-migration patterns.

It is commonplace to assume that areas for which agricultural enterprise constitutes a major economic base are apt to experience migration losses as agricultural production becomes increasingly mechanized and productive and capital intensive. However, previous research demonstrates that (1) where production is highly land intensive or (2) where large volume and capital-intensive production of food and fiber predominate, positive net migration is a likely outcome (Frisbie and Poston 1978b). The explanation of these findings is, in the first instance, that highly land-intensive agriculture has also tended to be labor intensive, and the greater the number of persons who can be productively engaged per land unit, the greater the likelihood of population growth due to migration. In the second case, capital-intensive, commercial agriculture, which corresponds neither to the land-intensive nor land-extensive type of utilization but which involves large volume and heavily mechanized production, creates an expansion of job opportunities and, thus, positive net migration as a complex of ancillary agribusiness establishments develop. It is also reasonable to assume that large-volume producers will be more likely to require full-time labor, which with respect to both the number of workers and their skill level, is beyond the resources of small-scale "family" agricultural enterprise.

A useful measure of technological inputs into the first type, i.e., land-intensive production, is tons of fertilizer applied per acre farmed. In the case of large-scale, commercial agriculture, an important indicator of applied technology is expenditures on machinery per acre. In regard to both of these "application-specific" technology measures, the argument suggests a positive relationship with migration.

Perhaps the most obvious operationalization of agricultural technology is expenditures on gasoline and petroleum products per farm. At first glance, one might expect that this variable also would be related positively to population growth due to migration. However, areas with high expenditures on gasoline and petroleum consumed in farm production are likely areas specializing in land-extensive agriculture. Frisbie and Poston (1978b) observe that this type of activity has to do mainly with the production of livestock on rangeland often incapable of generating a crop directly available for human consumption. Such land is productive principally "because ruminants are able to convert forage to meat or milk and the land area required per animal unit is likely to be quite large ... in areas devoted to ranching ... [And in this type of environmental setting] less labor is needed to make optimum use of rangeland than is involved in growing crops" (Frisbie and Poston 1978b: 48). Consequently, counties in which land-extensive, agricultural technology contributes significantly to sustenance extraction are unlikely to provide substantial employment opportunities. Such areas are thus expected to experience population decline via net out-migration. Accordingly, one would hypothesize that a negative association should exist between expenditures on gas and petroleum per farm and migration.

Regarding the transformative component of sustenance acquisition, a useful indicator of the employment of available technology is new capital expenditures. These include expenditures "for permanent additions and major alterations to manufacturers' operating plants, as well as for new machinery and equipment purchases that were chargeable to fixed-asset accounts, ... Expenditures include the cost of plant equipment for replacement purposes, as well as for additions to productive capacity" (U.S. Bureau of Census 1978: xliii). Not included are costs of land, mineral rights, maintenance, or repairs.

Thus, new capital expenditures will index at least the hardware and capital-equipment dimension of technology in the manufacturing sector, i.e., the capital goods, equipment, and machines that figure prominently in the definitions of technology cited above. Of course, it is possible that capital may be substituted for labor, so that high levels of new capital expended might well mean a leveling off, if not an outright reduction in, local employment opportunities. If so, the absolute magnitude of capital expenditures is expected to be inversely related to migration. Indeed, precisely such a zero-order negative association with net migration is observed in counties of the South in research by Poston and Frisbie (1984).

Finally, it is noted that the causal direction of the relationship between new capital investments and migration may be a matter for debate. For example, if firms in the manufacturing sector correctly anticipate that future labor costs will be insupportably high, new capital expenditures aimed at substituting for labor might result. One reason for expecting higher labor costs is out-migration. However, it is not clear that such a sequence of events is at all probable. In fact, Hawley argues that "migration flows from areas of low rates of capital investment to areas of high rates of capital investment" (Hawley 1950: 330). Hence, one should anticipate a positive relationship between net migration and the rate of new capital expenditures with the predominant causal path being from the latter variable to the former.

Environment

In human ecological terms, the environment is defined as "whatever is external to and potentially or actually influential on a phenomenon under investigation" (Hawley 1968: 330). The concept of environment occupies a central position in the general theoretical framework of human ecology mainly because the environment is the ultimate source of sustenance for a population (Hawley 1968: 330). However, little empirical research in sociological human ecology takes the environment directly into account, perhaps because of its breadth. That is, by definition, the environment "has no fixed content and must be defined anew for each different object of investigation" (Hawley 1968: 330). In fact, some hold that the environment is the "least well conceptualized of the variables constituting the ecological complex" (Berry and Kasarda 1977: 14).

However, close scrutiny of the ecological treatment of the environment reveals an implicit specificity not apparent in the above general definition. The environment comprises not everything external to the phenomenon of interest, but only those externalities that, by virtue of the limits they set on the acquisition of sustenance, affect the life chances of an organized population with a given technological repertoire. In other words, "the environment is viewed as a set of limiting conditions, which may be narrow or broad, depending upon the technological devices and modes of organization that prevail in a given population" (Schnore 1958: 628; see also Michelson [1970: 24–25]). Therefore, the human ecologist must logically narrow the arena of inquiry to those factors that, in light of existing technology, serve as limiting (or enabling) resources for the adaptation and growth of populations. The following paragraphs are intended to further sharpen this focus. It will be useful first to describe the sort of factors that are not included under the environmental rubric.

It is apparent that the outcomes of a population's organizational and technological operations on the environment and the adaptations or maladaptations thereby achieved often have been mistaken for the environment itself. Consequently, indicators of the state of a population's life chances, or quality of life, sometimes have been loosely categorized as "environmental." With such a definition of the environment, one might include such things as the prevalence of crime and other deviant activities, mortality and morbidity rates, unemployment rates, industrial structures, levels of education and income, and so forth. For example, one often hears that some environments are more violent or criminal than others. In the same way, one might speak of a political or economic or cultural environment or "climate." Regardless of the stylistic elegance of such phrases, this indulgence in metaphor quickly and easily destroys the precision required in empirical analysis. Put differently, the issue is much more than merely semantic, since the logical result leads to the conclusion that everything is the environment, except the population under study.

Therefore, it is not useful to consider social and economic activities (or aberrations) of local populations to be part of their environment. Certain of these activities, for example, employment in given industries, are best viewed as aspects of ecological organization. Others, such as crime and deviance, rates of mortality and morbidity, unemployment, education, and income levels, are best conceived as indicators of different aspects of life chances that emerge from a population's organized efforts to adapt to the environment. In a very real sense, the latter variables tend to indicate the degree of success or failure of the adaptive process. In short, they may reveal a disequilibrium between population and life chances. As such, they should be useful in helping to account for variation in migration and thus should be included in models designed to explain migration. But they should not be conceptualized as aspects of the environment.

Inevitably, efforts to circumscribe a concept involve decisions of both exclusion and inclusion. To this point, discussion has concentrated on the types of factors that should be excluded from the environmental rubric. Attention is now directed to those factors that may reasonably be included within the bounds of the concept of the environment. Although a certain degree of arbitrariness is unavoidable in setting conceptual boundaries, such circumscription is necessary for orderly analysis.

Despite the difficulties that arise in attempts to give conceptual and operational substance to the concept, it is clear that the ecological environment has two broad and distinct dimensions: the physical and the social. Hawley writes:

> Environment ... includes not only the physical and biotic elements of an occupied area but also the influences that emanate from other organized populations in the same and in other areas. In certain circumstances the latter acquire a more critical importance than the former (1981: 9).

Specifically, Hawley has distinguished two dimensions, the biophysical and the ecumenic. The "former includes physiographic features, climate, soil characteristics, plant and animal life, mineral and other materials," and so forth. In contrast, the ecumenic refers to the "ecosystems or cultures possessed by peoples in adjacent areas and beyond" (Hawley 1986: 14).

Attention is first directed to these broad typological considerations and then toward finer-grained distinctions. The physical environment, of course, refers to such things as climate, natural resources, and topography. In addition, one may distinguish aspects of the man-made physical environment (Michelson 1970: 1976), such as types of buildings and other physical structures. The social, or in Hawley's words, the ecumenic, environment refers to other populations and organizations that influence the populations being investigated.

Cross-sectional analyses have found certain climatological aspects of the physical environment to be associated with population redistribution (Poston and Mao 1996, 1998; Poston and Musgrave 1999; Walther and Poston 2004). Measures pertaining to temperature have been key in these and related considerations of climate; sometimes temperature serves as the only consideration (Karp and Kelly 1971; Graves 1980; Poston and Mao 1996; 1998). A temperature index typically involves the measurement of average daily temperature during a cold month such as January, or a warm month such as July; the two measurements are highly related (Poston and Musgrave 1999).

In recent research, Poston, Gotcher, and Gu (2004) analyze the states of the United States regarding the effects of physical climate on three migration rates for the 1995 to 2000 period, namely, in-migration, out-migration, and net migration. They gather data on 11 climate variables and use factor analysis to reduce them to the three dimensions of temperature, humidity, and wind. They show that the temperature and humidity dimensions are significantly associated with one or more of the three migration rates.

They also show that the effects on migration of the climate variables are sustained even after controlling for the effects on migration of factors dealing with ecological organization, the social environment, and population.

The above analyses are cross-sectional. When undertaking longitudinal investigations of changes in migration, a logical difficulty emerges. The climate of any area changes very slowly and over extremely long periods of time. Thus, while there may be some year-to-year fluctuations in temperature or rainfall in analytical units such as counties, states, or provinces of a country, climate is, for all practical purposes, invariant. To employ change in climate as a substantive explanation of population change due to migration in, for example, a one- or two-decade interval amounts to attempting to explain variation with a constant.

Although measures of the physical climate have been shown to have some utility in cross-sectional studies of migration, it is also useful to draw on natural environmental factors that show more temporal variation when affected by technology and organization. Thus, playing an important role in the measurement of the physical environment should be variables such as air quality (e.g., mean levels of suspended particulates of sulphur dioxide), mean annual inversion frequency, and a water quality index (Liu 1976).

There are also aspects of the man-made physical environment that may affect both net and gross migration patterns. Foremost is the availability and nature of housing stock, although one may debate the direction of the causal influence. That is, one might argue that population growth is a cause rather than a consequence of the construction of housing. However, evidence from the sociological literature suggests the primary causal flow to be from new housing to population change and not vice versa. To illustrate, regarding suburban growth, Guest (1978: 254) concludes that "population growth is primarily determined by the creation of new additional housing units." And Marshall (1979: 991) suggests "that population redistribution is largely a function of the redistribution of dwelling units," a conclusion congruent with research by Schnore (1965), Duncan, Sabagh, and Van Arsdol (1962), Guest (1973), and Krivo and Frisbie (1982).

Regarding the social, or ecumenic, environment, two entities have substantial influence. First, the ecological linkages of sustenance exchange are mediated and controlled through large, dominant metropolitan centers, a finding that has been shown to obtain in the United States and in China (Vance and Sutker 1954; Duncan et al. 1960; Poston, Tian, and Jia 1990; Poston and Gu 1993). Although usually applied mainly to urban areas, one can argue that no section of large industrialized countries is isolated from metropolitan influence (Hawley 1971). Indeed, the factor "most frequently demonstrated to be related to changes in the number of inhabitants of counties, as well as cities, is that of propinquity to large urban centers" (Frisbie and Poston 1975: 780; see also Fuguitt and Thomas 1966, Fuguitt 1971, DeAre and Poston 1973, Frisbie and Martin 1973). Virtually all prior research leads to the conclusion of a positive effect on migration of an area's proximity to a metropolitan area. Several measures of the latter variable are available. Size and proximity to the nearest metropolitan area, as measured by an index of proximity developed by Hathaway and his colleagues (1968), are used as one indicator. An alternative operationalization, construction of a dummy variable scored 1 if the area is adjacent to a metropolitan area and 0 if not, is also relevant.

McCarthy and Morrison (1979) find convincing evidence of the significance of urban influence on population change in general and migration in particular. They note that a nonmetropolitan county might be affected by the commuting of local population to metropolitan centers as well as by "urban influence" per se. Urban influence may be interpreted in two different, but interrelated, senses: (1) the economic and organizational dominance of metropolitan areas adjacent to the county and (2) the influence of urban populations within the county. After careful examination and comparison of the relationship between commuting and information on counties' adjacency to metropolitan areas, McCarthy and Morrison conclude that "knowing a county is not adjacent to a metropolitan area is tantamount to knowing that very few of its residents commute to metropolitan labor markets" (1979: 23).

Of course, population aggregates and organizations other than those immediately adjacent to the geographical unit of analysis may also exercise a social environmental, or ecumenic, influence, as understood by human ecologists. Hence, a second social environmental influence on geographical units is that emanating from extra-local, especially federal, governments. For instance, a generally positive relationship is expected between the proportion of the area's population employed by the government and population change due to migration, if for no other reason than the job opportunities associated with this extra-local source of employment. With regard to another measure of government influence, the proportion of local revenue attributable to governmental sources, it is also reasonable to expect a positive relationship with migration, because increased extramural revenues should lead to a general improvement of quality of life. Conversely, there is growing evidence that significant numbers of persons have begun to migrate from places where extensive governmental services are provided at least partly because of the heavy influence of government in their daily lives and the higher taxes associated with provision of those services (Kasarda 1980). Areas in which federal monies constitute a disproportionately large share of local revenues are apt to be depressed areas incapable of generating sufficient funds for their own maintenance. Under either interpretation, areas with high levels of federal governmental revenue inputs would not appear to be attractive destinations for migrants. Thus, it is plausible to expect that high levels of federal employment should be associated with positive migration change, while federal revenue proportions have an opposite effect.

CONCLUSION

This chapter has several objectives: (1) to provide a general outline of the ecological orientation; (2) to distinguish human ecology from ecological demography; (3) to discuss and review the explicit focus of ecological demography, namely, the application of human ecological theory to empirical investigations of the demographic processes; and (4) to show the importance and relevance of human ecology specifically for the study of the demographic process of migration.

It was necessary to first set out the general orientation of sociological human ecology, mainly because of the fact that even today, despite the immense number of publications providing evidence to the contrary, the field is still misunderstood by many sociologists and social scientists to be either a descriptive exercise or any kind of aggregate analysis. It was shown in the first and second sections of this chapter that some still believe that human ecology represents spatial or aggregate investigations of human phenomena. This representation minimizes considerably the rich sociological context of human ecology and indicates misunderstanding, perhaps even ignorance, of its orientation and subject matter.

The broad theoretical purview of human ecology has been distinguished from the narrower focus of ecological demography. Human ecology is concerned with the organizational aspects of human populations that arise from their sustenance producing activities. For the purposes of this chapter, it was noted that human ecology offers demography a specific aggregate perspective for the analysis of the demographic processes. The third section reviewed in detail the relevant literature of ecological demography.

The final section of the chapter outlined and articulated the theoretical and empirical ties between one demographic process, net migration, and the four basic referential constructs of population, organization, environment, and technology. In a review of the empirical and theoretical literature spanning more than five decades, it was shown that demographic models of migration benefit from use of the ecological perspective. Accentuated were the explicitly sociological features of the ecological perspective in a demonstration of its fruitful employment in demographic investigations. The strictly spatial studies that so many have thought to be ecological not only are not ecological, they are usually not sociological. Moreover, they are theoretically lacking and are of little utility for demographic investigations.

It is the contention of this chapter that human ecology holds great potential for informing demographic study, particularly if it maintains its sociological emphasis on sustenance organization. We believe that the materials presented and developed here support such a conclusion.

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