Population Nucleation and Functional Interdependence in Prehistoric Coastal Ecuador

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ABSTRACT

Increased specialization within communities is often explained as an epiphenomenal effect of political expansion and surplus accumulation. Here, I examine the possible role that community demography and settlement structure might have in promoting (or inhibiting) full-time specialization and interdependence in the functions of various social institutions. Through the use of multivariate iconographic representations and diversity indices this article puts forth a methodology for the systematic large-scale comparison of archaeological remains and tests it on three prehistoric settlements in coastal Ecuador. The results indicate that nucleated communities exhibit more evidence of internal functional differentiation and interdependence in social roles than dispersed ones. This suggests that larger networks of interaction might provide ripe social environments for increased specialization of activities. By contrast, dispersed settlement arrangements and the smaller networks of interaction they make available seem to pressure households into becoming increasingly autonomous and self-reliant, resulting in strong tendencies towards functional redundancy.

INTRODUCTION

Throughout the bulk of prehistory, humans organized around kin groups to secure adequate returns for their biological and cultural viability (Netting 1993). Although highly variable in terms of

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make-up, size, structure, and focusing on widely different resources and environments, co-residential domestic units were not only the central fulcrum around which subsistence activities were structured (Earle 2002; Sahlins 1972), but also the fundamental productive entity responsible for manufacturing goods necessary for cultural reproduction (production of culturally acceptable garments, necessary ritual paraphernalia, ceramic wares for ritual and utilitarian use, *etc*.). In recognizing the co-residential unit as the essential reproductive building block for most of prehistory, researchers provided terminology meant to distinguish this basic mode of organization from those appearing in more complex types of societies. Sahlins (1972), for example, used the term Domestic Mode of Production One (DMP 1) and more recently Earle (2002) used the term domestic economy for this baseline household form of organization inherit to prehistoric populations.

Until the appearance of institutionalized hierarchy most production took place under this DMP 1 in which the domestic unit was highly autonomous and relied fundamentally on its own labor for self-perpetuation (Netting 1993). Co-residential members of working age devoted the bulk of their time to subsistence production for the benefit of their own specific household and addressed their need for ancillary goods, services, and culturally dictated activities by allocating some of their internal labor power to these endeavors. Some kin communal pooling of labor for supra-household goals certainly took place, but important here is that until the appearance of institutionalized leadership the prehistoric record shows little evidence that non-subsistence activities were resolved through the use of full-time specialist households within communities.

Comparative analyses of prehistoric societies around the world corroborate this most clearly for the realm of craft production, and indicates that full-time craft-specialists – such as medieval European blacksmiths who did not engage directly in subsistence pursuits, but traded their craft-items for resources from the subsistence sector of the economy – were rare if not altogether absent in communities dominated by the DMP 1 (Clark and Parry 1990). Supra-household need for labor (such as that for community projects or warfare) was also rarely addressed through any type of household specialization. For example, throughout most of prehistory societies engaged in warfare predominantly through able-bodied males that tended to their own household's subsistence needs for the bulk of their time, and lacked clear full-time specialized warrior classes (Keeley 1996). Under this setup, each domestic unit's involvement in supra-household activities was satisfied by allotting a portion of their available labor to those ends, making each household's participatory role in these activities structurally homologous to that of every other household.

Similarly, informal leadership of the community could be achieved by certain individuals on a temporary basis based on prestige, a costly commodity but one that was open to any household since they all possessed roughly homologous compositional structures within DMP 1 societies (Drennan 2000; Earle 1993, 1997; Sahlins 1963). More importantly, prestige-based informal leadership did not bestow the ability to tax other domestic units, and hence did not transform the economic compositional structure of the temporary elite household to one that could sustain itself through taxation. The result was that even when a household was able to attain a leadership role within its community, it still needed to focus the bulk of its labor force on meeting its own internal subsistence and cultural needs. Even shamanic roles do not appear to be exempt from these general structural constraints of DMP 1 societies, as they were predominantly filled by individuals who during their abled bodied years carried out direct subsistence pursuits alongside others in the community, and who only directed community rituals, rites of passage, and mediated supernatural forces as needed or as cultural norms dictated it (Sanderson and Roberts 2008).

The scenario for DMP 1 societies, then, is one where many structurally homologous domestic units – each with equal structural access to supra-household rights and obligations – look to meet their own subsistence needs independently from one another and must carry out other endeavors as supplemental part-time activities. The result is that each reproduces the same general array of activities (subsistence or otherwise), which is responsible for a high degree of functional redundancy in the behavior of households that constitute the basic building blocks of DMP 1 communities. For the production of non-essential goods, but also in their role in warfare, decision-making structures, and other types of supra-household activities.

In some parts of the world, however, structural differentiation of these elemental social building blocks took place, although it is still unclear precisely why this happened in some societies and not in others. Through the extraction of surplus from domestic units it became possible to finance an institutionalized elite upper class, allowing some households to withdraw completely form direct subsistence endeavors as they became full-time political leaders (Earle 1997; Sahlins 1972). This funneling of resources to specific elite groups allowed the financing of more coercive political apparatuses, the building of project works, increased the array of luxury goods produced, *etc.* This distinct mode of production derived from tribute extracted from the domestic economy is what researchers have termed the political economy or the DMP 2.

In most regions of the world, the composition of this elite upper class – although functionally distinct from the matrix of domestic units from which they arose – retained a fairly internally homogenous character. The fundamental distinction seems to have been one of degree based on lineage proximity to the ruling chief, with lesser regional chiefs and their families being homologous equivalents to the paramount chief, with similar abilities to tax, coerce, and administer justice, but further down-the-line of succession and administering smaller subsets of the total political entity.

In places like the central Andes, Mesopotamia, and Mesoamerica, however, the roles within these administrative upper classes became so functionally specialized that specific roles were developed for record-keeping bureaucrats, administrators, tax collectors, judges, *etc.* Each with distinct segments of political authority but lacking others, and subservient to a yet more functionally distinct elite upper class (Spencer 2010). These types of political formations – for which the term 'State' is usually reserved – seem to have been composed of highly functionally interdependent governing institutions when compared to those DMP 2 chiefly societies where the ruler class was not highly differentiated (Wright and Johnson 1975; Wright 1977). Because they encapsulated larger territories, and hence tributary bases, their political economy also exerted tenure over much larger pools of accumulated surplus.

It is in societies of this type that comparative analyses tend to recognize the presence of full-time specialization for various other social institutions. Most notably, craft-specialists who are fundamentally withdrawn from direct subsistence pursuits and trade their craft products for resources from the subsistence sector of the economy are strongly correlated with state-like societies (Clark and Parry 1990). Likewise, states regularly exhibit full-time canonic specialist, financed by religious institutions with discrete interdependent functions, highly compartmentalized roles, and able to decree and regulate strong normative canonic dictums (Moore 2006: 85; Sanderson and Roberts 2008). For warfare, Keeley (1996: 47–48) explicitly notes that cross-cultural quantitative analyses of the sophistication of military institutions show it to be tightly linked to that societies' economic structure, in particular its ability to harness and re-direct surplus in a sustained manner (see also Arkush 2011: 61–62; Otterbein 1989). He credits a constant well-regulated influx of economic surplus for allowing some military institutions to compartmentalize and support full-time military specialists, which Keeley invariably notes as a distinct license of bureaucratic states.

PROPOSED CAUSES

Although we can discern a general trend of increasing functional interdependence in social institutions through prehistory, and at least some indication of what may have led to these developments, we are still unclear as to exactly why functional interdependence increases in some places and not others, and which social institutions seem to be at the root of these changes.

Most research on this topic has focused on explaining this phenomenon through the need of expansionist polities to tax and administer increasingly larger populations. This tradition sparks from Carneiro's (1981) seminal work on supra-local incorporation of polities, which sees increased functional interdependence as a necessary transformation of growing political entities. An especially useful clarification of the mechanics of this transition is provided by Charles Spencer (2010), who proposes that most societies are stuck in a phase of chiefly cycling where they do not develop interdependent bureaucratic apparatuses precisely because chiefs do not segment their power. As new populations are incorporated into the growing polity through military subjugation, lesser chiefs – needed to administer newly conquered territories – are able to contest the authority of the paramount chief because they are functional homologues. This makes chiefly political institutions inherently unstable, and likely to result in the constant fragmentation of non-bureaucratic political entities (hence the term ‘chiefly cycling’).

In only a few places around the world, however, Spencer suggests that chiefs parceled their authority into functionally interdependent roles, allowing subordinate administrators to carry out only specific responsibilities without authority to carry out others (*i.e.* the ability to garner taxes versus the ability to dispense sentences). This begat much more stable political institutions that did not put in jeopardy ruling lines of succession or the continuity of the expansionist polity, which Spencer argues allowed territorial expansion to continue through many more successive generations and encapsulate much larger populations. Under this scenario, functional interdependence occurs first within political institutions; subsequent interdependence in craft production, military roles, or religious institutions takes place as the increasingly larger surplus accumulated by the political elites allows them to finance full-time attached specialists (Costin 1991).

However, the prehistory of humankind plainly shows that not all societies had historical trajectories towards increased functional interdependence. Not only did many prehistoric populations not internally differentiate so as to take advantage of the added efficiency associated with interdependence, but there also does not seem to be a simple developmental sequence towards more differentiated social roles through time. Many societies underwent millennia retaining strong tendencies in functional redundancy for their composite units (Wenke and Olszewski 2007: 287–288), and those that did internally differentiate more strongly seem to have done it in different ways and at different tempos (see, *e.g.*, Drennan and Peterson 2006; Fox 2010; Palumbo *et al.* 2013). With specific relevance to Spencer's model, the question is why were some societies able to parcel their political authority and not others? It is also possible that increased functional interdependence in other social institutions (military, religious, economic, or otherwise) was not the result of the parceling of political authority, but rather that some other phenomenon motivated interdependence of these various facets of human life simultaneously. This makes it important to disentangle what contexts favored the appearance and development of functional interdependence – or which ones inhibited it, and how this phenomenon varied from one place to the next.

POPULATION NUCLEATION AND NETWORK SIZE

For modern times, Gelfand and colleagues (2011: 1102) have shown a strong cross-cultural correlation between high population density and cultural variables such as more structured and strict regulatory social institutions. Likewise, recent settlement analyses for traditional and prehistoric societies have also hinted at the importance of settlement structure as a critical component in the development of more complex forms of social organization (see, *e.g.*, Bandy 2010; Frechione 1990; Martín 2010b; Palumbo *et al.* 2013). Here, I focus on the degree to which population nucleation – defined as a densely packed settlement structure with domestic units residing in close proximity to one another – favors the development of functional interdependence. This idea has already been highlighted by authors such as Peterson and Drennan (2005: 8–9), and has received increased analytical attention by researchers focusing on prehistoric demography and settlement structure in recent years (Berrey 2015; Martín and Murillo Herrera 2014; Palumbo *et al.* 2013).

By definition, dispersed settlements have homogeneously low population densities across space. If populations are evenly spread out across a large area, no matter where a person travels and how much distance they cover, they encounter only a few scattered households at any given location. This means that dispersed settlements provide constantly low levels of interaction no matter how much energy is invested. By contrast, nucleated settlements intrinsically provide high levels of interaction at set locations. For production, this means more consumers requiring a wider array of goods at close range, while a lowering of trade and transport costs (Drennan 1984a, 1984b). More importantly, a large and easily accessible population also makes it increasingly possible for individuals to devote themselves to full-time specialized work because of economies of scale.

To illustrate this, consider two networks of people, one with ten individuals, and one with 1000. For the network of ten, having one individual become a full-time ceramicist would not only be very costly and punitive to that network's total labor force (by lowering by one tenth the labor force available to carry out every other task), but would also not provide sufficient constant consumers of ceramics to validate such a high investment to the network. This would be even more pronounced for types of products consumed with less frequency than ceramics (*i.e.* the production of wealth ornamentation or of ritual paraphernalia). By contrast, in a community with 1000 individuals, not only is losing a single individual out of one thousand much less punitive to the network, but it also leaves 999 available consumers of the craft worker's products. Essentially, decreasing the amount of people in your network decreases the permissibility of any individual dedicating to a task full-time. Because of their perennially low population densities, dispersed settlements provide only small networks at any given locale. By contrast, nucleated settlements make available much larger networks to their residents and immediate neighbors.

It is important to note that this relationship between network-size and specialization is not just relegated to production, but also applies to administration and services. For administrative institutions, for example, large populations raise the amount of internal social conflict and stress a community experiences (Bandy 2010; Carneiro 1987; Service 1962). Traditional communities often mitigate this through fission (Bandy 2010; Frechione 1990), but in places where fission cannot occur (either because resources are geographically restricted, for defensive reasons, or otherwise) population nucleation may require the formation of a more structured administrative apparatus (Bandy 2010: 32; Bandy and Fox 2010: 13–14; Martín 2009a, 2010b). This process is aided by the fact that the amount of surplus each domestic unit needs to relinquish to finance full-time political elites is proportionally lower per-capita in larger communities than in smaller ones (Martín 2010b: 148–149). More importantly, the same principles of network size that apply to the organization of economic endeavors also apply to decision-making institutions. It is less costly for a larger network to lose a single individual to full-time administrative work than for a smaller one. Hence, nucleated communities with more members, more interaction and conflict, and a larger array of managerial problems to solve, would increasingly require better and more efficient forms of administration, but at the same time would have a more propitious demographic context for the development of more specialized and differentiated types of administration.

In the last decade, social scientists have provided increasing evidence that canonic institutions developed in early prehistoric communities to incentivize and regulate prosocial behavior, which encourages altruistic, reciprocal, and orderly conduct amongst non-kin (Norenzayan and Shariff 2008). In as much as canonic institutions conform to these types of managerial structures, they would benefit from population nucleation and an increased numbers of participants, with its inherent predisposition to facilitate differentiation, functional interdependence, and the benefits in efficiency they garner. To this point, it is precisely the demographic context of a community member that determines the permissibility of them completely withdrawing from subsistence production and carrying out religious ceremonies as full-time specialists. As noted above, Keeley (1996) proposes a similar argument from cross-cultural comparisons of the sophistication of military institutions.

By contrast to nucleated villages, when domestic units are dispersed, their available network of interaction is capped regardless of location. This interaction ceiling means that domestic units interact with much fewer households as they handle their daily affairs, making it more prohibitively costly for those individuals to relinquish subsistence activities and work full-time at providing specialized goods or services (in addition to reducing the number of constant consumers of those same goods or services). Less full-time specialists would furthermore pressure domestic units to become increasingly autonomous and self-reliant, having to resolve on their own as many issues related to their biological and cultural reproduction as possible (including production of subsistence goods, clothing, ritual paraphernalia, *etc.*). This would discourage the production of items and services that are utilized less frequently or that are too costly for domestic units to produce and consume entirely on their own. The result would be a highly functionally redundant social landscape, with each domestic unit similarly reproducing the same array of goods and services they need to go about their daily routine, but limiting these goods and services to those that can be sustained by small networks of less efficient part-time producers.

These two contrasting scenarios between dispersed and nucleated settlements provide predictable archaeological expectations of social composition within communities. If nucleation truly provides a more propitious social environment for functional interdependence, then it would be expected that more nucleated prehistoric populations should show higher degrees of internal differentiation than dispersed ones. As noted above, functional interdependence may take many forms and researchers are still unsure as to precisely how different social institutions are affected (*e.g.*, a larger network might facilitate interdependent productive strategies differently than administrative ones). Still, the prediction would be that the constituent units of nucleated communities should be more distinct from one another than those of dispersed settlements. It would also be expected that nucleated communities should exhibit additional cultural elements not present in dispersed settlements since larger networks facilitate the production of a wider array of goods and services. By contrast, the component units of dispersed populations should be much more repetitive and homogenous across space. Since small networks also limit the array of goods and services that can be produced, these domestic units should also show less variety in the types of cultural remains they exhibit.

Unfortunately, even though we have come a long way in modeling social practices and developed sophisticated predictions of how prehistoric societies should look depending on how they were organized, it is still very difficult in archaeology to measure these kinds of expectations empirically for large areas in systematic ways. This is mainly because it is very costly and time consuming to carry out detailed excavations of a large number prehistoric households with consistent methodologies so that artifact categories may be compared, much less investigate all of the households that could constitute a large community. If one wants to compare several communities, the task is even greater. Recent years have seen great advances in our understanding of prehistoric productive strategies and community specialization from comprehensive excavations of targeted locations (see, *e.g*., Carballo 2011; Feinman *et al.* 2002; Shimada and Wagner 2007). However, it may be beneficial to also focus on sampling techniques that allow us to get a larger number of observations from across entire communities while still collecting representative data about the variation of artifacts at each location. This could provide useful information about overall community composition that would complement more localized approaches and targeted excavations.

Specifically, there are two types of information that would increase our understanding of the distribution of activities within a community. First, we need to know how different types of cultural assemblages are distributed across an occupation so as to understand how activities varied from one location to the next. Second, we need to reconstruct the densities of cultural material across each settlement to pinpoint the places where people concentrated more strongly. This information should be gathered systematically for all locations with a high degree of precision to allow comparisons of social practices at different locations and recognize subtle changes in population dispersion or concentration for large territories.

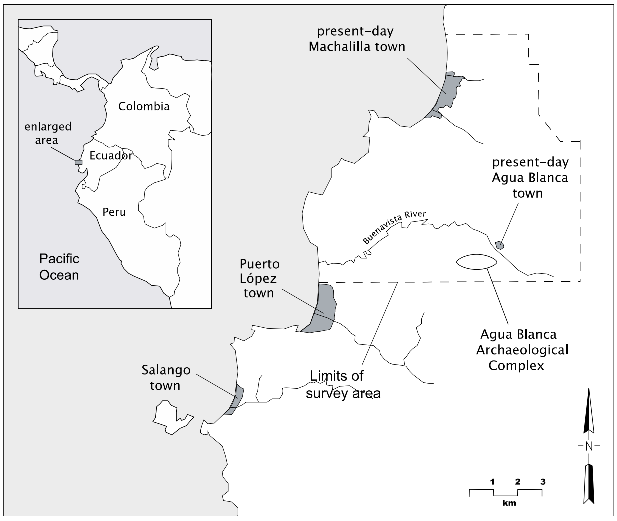

Fig. 1. Location of Southern Manabí, Ecuador, including delimitations of the study area and modern settlements

Following methodologies developed by Drennan (Drennan *et al.* 2015; Peterson and Drennan 2005), here I describe a potentially useful way of probing community composition using artifact samples collected from a pre-Columbian occupation over an area of roughly 100 km^2 in the region of southern Manabí, coastal Ecuador (Fig. 1) (Martín 2009a, 2009b). A systematic full-coverage survey there revealed a set of synchronous prehistoric settlements that ranged from highly nucleated towns to dispersed isolated farmsteads. These varying settlement types provide us with a valuable opportunity to measure the expectations of population nucleation and interdependence outlined above. The aim is to evaluate the usefulness of large-scale analytical techniques for comparing settlement composition, thus expanding our tool-kit for measuring phenomena like functional redundancy or interdependence in systematic ways.

THE PREHISTORIC SOCIETIES OF SOUTHERN MANABÍ, ECUADOR

Archaeological investigations in coastal Ecuador have revealed that the populations of southern Manabí did not exhibit much evidence for institutionalized leadership, supra-local consolidation of villages, or population nucleation until the beginning of the Integration Period (ca. 700 A.D.) (Delgado-Epinoza 2002; Martín 2010c; Masucci 2008; Muse 1991). At this time, changes in demographic composition and political structure seem to sprout from increased trade connections with the large state-level societies of northern Peru (Martín 2007; Pillsbury 1996; Shimada 1994), which prompted coastal Ecuadorian populations to concentrate around specific areas where trade resources could be harvested (Martín 2010c). Archaeological excavations and surveys along the Ecuadorian coast have in fact revealed a thriving large-scale cottage manufacturing industry of ornamental items for trade, particularly from *Spondylus* and two oyster species (*Pteria sterna* and *Pinctada mazatlanica*) (Currie 1995; Harris *et al*. 2004; Marcos 1977/78; Masucci 1995; Mester 1990; Muse 1989; Zeidler 1991). The resulting population nucleation around coastal towns appears to have promoted the formation of chiefly managerial structures that facilitated orderly community interaction and minimized internal social conflict (Martín 2010b: 148–149). It is at this time that we also see evidence for supra-local polities that consolidate regional populations. There is no evidence, however, that these polities ever developed the highly interdependent and compartmentalized bureaucratic positions that characterize their state-like neighbors to the south. Rather, they fit closer with Spencer's (2010) definition of supra-local chiefdoms where institutionalized elite upper classes extracted surplus from the general population but without any robust parceling of political authority, making them highly susceptible to chiefly cycling (McEwan and Delgado-Espinoza 2008).

Here, I focus primarily in probing the community structure of these populations during the Integration Period (A.D. 700–1532) since it provides both the first clear evidence of complex social organization in the region, as well as the first visible evidence of large nucleated towns along the coast of Manabí. However, more detailed information about the trajectory of development, culture history, productive strategies, and political structure of these societies, from Formative times to European arrival, is provided in Martín (2009b, 2010a, 2010b, 2010c).

The first step to systematically comparing different artifact samples in the communities of our study area was to delimit the extents of each settlement by mapping its artifact surface scatter (see Martín 2009a: 19–62 for details on surface conditions and visibility). Each continuous artifact scatter was then sub-divided into one-hectare collection units and a systematic sample of artifacts was gathered at the center point of each hectare (Fig. 2 shows an illustration of this approach). This systematic sampling strategy made it possible to reconstruct the varying changes in artifact density as well as variations in artifact type within and between settlements. The complete breakdown of the artifacts recovered is accessible electronically at Martín (2009b).

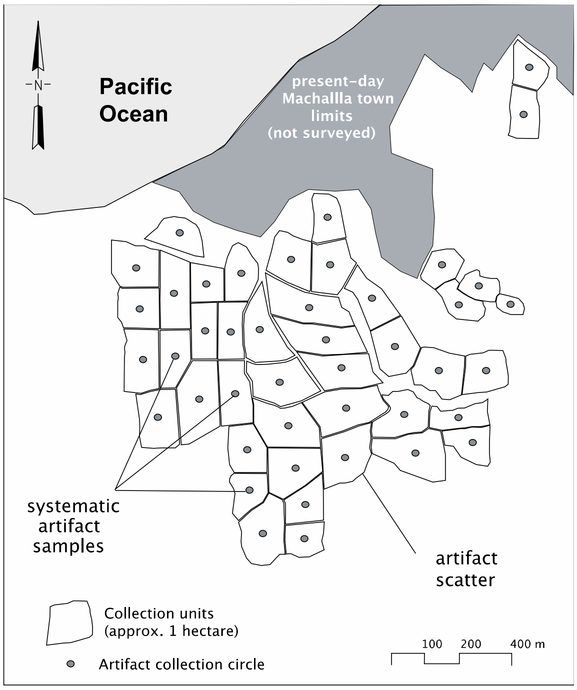

Fig. 2. Large artifact scatter broken down into one-hectare lots, with artifact samples taken at the center point of each lot

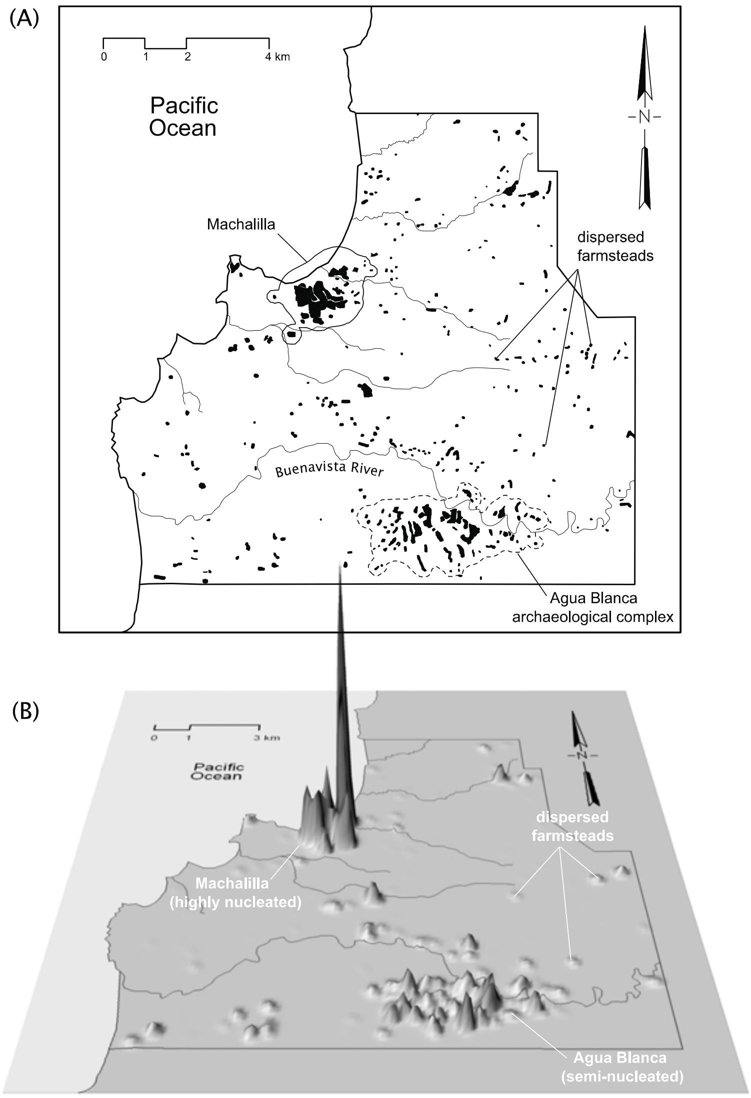

Fig. 3. (A) Location of all Integration Period (ca. 700–1500 A.D.) artifact scatters. (B) Ceramic density reconstruction where peaks represent areas of high ceramic density and flat areas are places where few or no ceramics were recovered

The resulting occupational distribution for the Integration Period is illustrated in Fig. 3. The image depicts both (A) a map showing each collection unit that produced ceramics belonging to the Integration Period; and (B) an isometric graph where peaks represent areas of high ceramic density and flat areas are places where few or no Integration Period ceramics were recovered. The density distribution of prehistoric remains (Fig. 3B) allows us to clearly distinguish three main settlement types with differing degrees of population nucleation: the highly nucleated prehispanic town of Machalilla, the semi-nucleated Agua Blanca occupation, and a dispersed scatter of isolated rural farmsteads at their hinterland. Evidence of shell manufacturing (in the form of shell debris and lithic tool-kits associated with the shell industry) is primarily concentrated on the coastal nucleated Machalilla community (Martín 2010b).

MEASURING HOUSEHOLD DIVERSITY

In accordance with our expectations, the constituent units of nucleated communities should be more distinct from one another than those of the dispersed settlements. They should also show a wider range of activities since larger networks enable domestic units to engage in the production of a wider range of goods and services. The artifact samples taken at one-hectare intervals provide useful indicators of artifactual variation across the three different settlement types – and by proxy, in the activities they represent.

To evaluate these expectations, the contents of each sample were graphically depicted using multivariate icons, which portray the quantities of different types of artifacts in each sample as 'arms' around a central axis (Fig. 4).

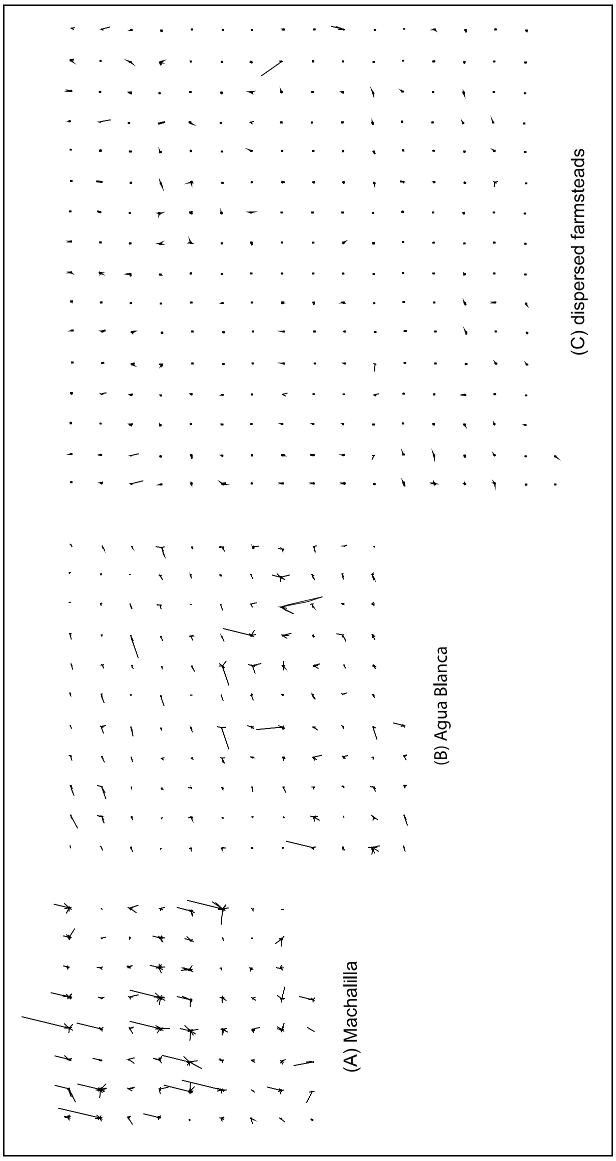

Fig. 4. Iconographic representations of 100 categories of different artifact counts for each sample gathered within the three delimited settlement types. Categories correspond to those of Appendix A and are depicted clockwise beginning at 12 o'clock

Artifact counts were taken directly from the Integration Period ceramic, lithic, and malacological inventories in Martín (2009b). Ceramics were sorted and cataloged into different types. It is important to note that the observations gathered represent averaged-out samples of the accumulation of Integration Period material over time, and should not be taken literally to represent precise synchronic comparisons of one moment in time. Instead, what is being compared is the average accumulation of material from one location to the next, so that those locations that produced more overall diversity can be discerned. The use of surface collections to represent activities was only undertaken after sufficient research justified a fairly dependable correspondence between surface and subsurface materials (particularly for the Integration Period) (see Martín 2009a, 2010a; 2010b for discussions of excavation and surface correspondence). Of particular importance here is that horizontal excavations have revealed that craft activities during this period took place mostly as cottage production associated with households (Carter 2008; Harris *et al.* 2004; Martín 2009a; McEwan and Delgado-Espinoza 2008; Mester 1990), which makes it possible to associate the indicators of craft production recovered by samples to household activities.

Priority was given to artifact types more likely to represent discrete activities. For example, the number of grinder sherds in a sample was included because it represents good evidence of food processing; worked *Spondylus* shell fragments provide evidence of ornament production; and chipped-stone debitage represents evidence of lithic-retouching, *etc*. Large undescriptive categories (such as 'unidentified ceramic sherds') were not included since they did not speak directly to function and their large numbers masked more meaningful variations in smaller categories that more directly represented discrete activities. In total, one hundred categories of artifacts are represented in each icon (or sample) of Fig. 4 with homologous categories represented at the same position (Appendix A provides the complete list of artifact categories included). This allows us to see with relative efficiency which samples had (1) large quantities of a single artifact type (long arms), and (2) which had many different artifacts types represented (many arms). Since we aim to compare differences based on settlement type, the samples have been grouped into the three settlements types noted above.

Fig. 4 reveals that a much larger proportion of the nucleated Machalilla samples had larger artifact counts in various categories, as well as tended to have more categories represented. This indicates that the compositional units that made up Machalilla (Fig. 4A) were more distinct from one another than those of the other two settlement types. More precisely, more of Machalilla's households show evidence of having focused on distinct activities when compared to those of the other two. Also, more of Machalilla's domestic units show evidence of a wider array of activities than those of Agua Blanca or the dispersed farmsteads.

The dispersed farmsteads (Fig. 4C), by contrast, have a much larger proportion of samples with similar composition, each with fewer categories represented, and few showing marked emphasis on a given activity. As predicted, the semi-nucleated settlement of Agua Blanca (Fig. 4B) falls somewhere in the middle of the other two, with a lower proportion of high-count/many-category samples than Machalilla, but more of them than the dispersed farmsteads.

A common concern with sampling strategies of this type is that different observations might gather artifacts from different contexts (say a kitchen midden in one case, versus a patio floor in another), which would intrinsically differ in artifact compositions due to function. In this case, however, it is precisely the variability in contexts within the three settlement types that we are trying to determine, and Figure 4 strongly suggests that household contexts varied more strongly within the nucleated Machalilla settlement than at the other two locations.

The use of raw counts can also be problematic because some categories are bound to intrinsically have greater counts than others (archaeological assemblages almost always produce several hundred utilitarian jar sherds for every elaborate figurine sherd that is collected, for example). This can make it difficult to spot unusually large quantities of artifacts in categories that tend to produce very small artifact counts. A way to address this is to represent the same categories of raw counts as standardized scores (by subtracting the mean artifact count for each category from the artifact count of a given sample, and then dividing this number by the standard deviation of that category). This essentially provides an index of how much a given observation deviates from the average of that category. This comparison of standardized scores, for example, expresses how unusual it is for a given sample to possess eight grinder sherds considering the average number of sherds recovered by every other sample within that settlement type (Drennan 1996: 44–51).

The standardized scores are illustrated in Fig. 5, which brings the same patterns visible in Fig. 4 into even sharper relief. Because the spread of the batches are much smaller, the icons are illustrated with a larger central axis so that more subtle differences can be depicted with clarity. Again, the nucleated settlement of Machalilla (Fig. 5A) has a much larger proportion of unusual observations in many more categories of artifacts, with a larger proportion of samples showing longer arms, as well as a greater number of arms. The dispersed farmsteads (Fig. 5C), again, tend to look overwhelmingly similar, with very few cases displaying unusual categories (and when they do, few of them). Finally, the semi-nucleated Agua Blanca occupation falls somewhere in the middle (Fig. 5B) with a lower proportion of samples exhibiting as many unusual categories as those of Machalilla (although it should be noted that those Agua Blanca samples that do exhibit unusual categories show considerably pronounced levels of unusualness with similarly long and as many arms as the Machalilla samples). As noted above, these comparisons do not represent a 'snap-shot' of a moment in time, but they show that throughout the span of the Integration Period more material diversity accumulated between locations within nucleated communities than between dispersed settlements.

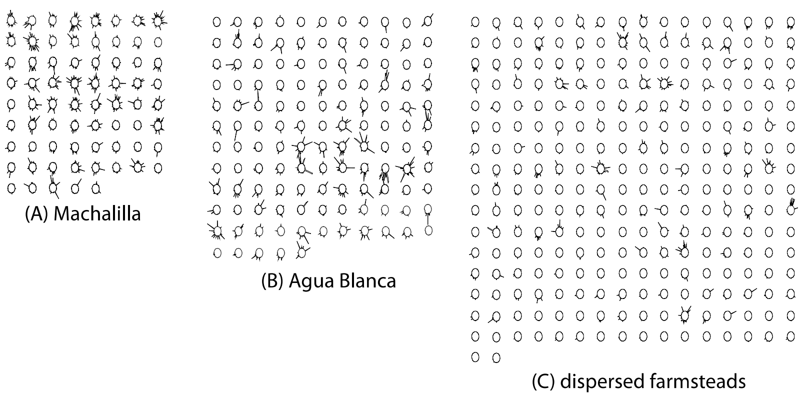

Fig. 5. Iconographic representations of 100 categories of different artifact counts (as standardized scores) for each sample gathered within the three delimited settlement types. Categories correspond to those of Appendix A and are depicted clockwise beginning at 12 o'clock

To corroborate these results, the variation between these settlements was also measured through a diversity index. Commonly used in biology for ecosystems, Simpson's D provides a score that measures the richness of a sample (the number of categories) and its heterogeneity (the distribution of elements within categories) by determining the likelihood that two randomly chosen elements will belong to the same category. Simpson's D is an open ended scale in which higher numbers represent more diversity, and was calculated separately for each of our samples using the same artifact categories and raw counts depicted in Fig. 4. If population nucleation provides a more propitious environment for functional interdependence to develop, it would be expected that the samples in the nucleated village of Machalilla would have – on average – higher D scores since its constituent units would have developed a wider range of activities. We would also expect the nucleated settlement to have more overall variation between its constituent households, some developing a varied set of specialized activities and some not. This should be manifested in a batch of samples with a wider range of diversity indices (a larger spread of the batch). By contrast, functionally redundant dispersed farmsteads should show less variation between constituent units (manifested in a smaller spread of the batch) as well as lower overall Simpson's D scores. This would indicate that households there did not develop a widely varied set of activities, but rather focused redundantly on the same narrow range of tasks.

Fig. 6 depicts the spread of D scores as box-and-dot plots grouped by settlement type. Again, the results conform to what is expected with the nucleated settlement of Machalilla showing both the highest average D scores ($\bar{x}_D$ =11.635 ±1.88 at 95 per cent confidence) as well as the largest spread of the batch. By contrast, the dispersed farmsteads display both lower overall D scores ($\bar{x}_D$ =6.449 ±0.76 at 95 per cent confidence) as well as a reduced spread. Finally, the semi-nucleated settlement of Agua Blanca falls between these two ends for both criteria, with and average D score of 7.977 (±1.09 at 95 per cent confidence) and a spread that falls somewhere between that of the other two.

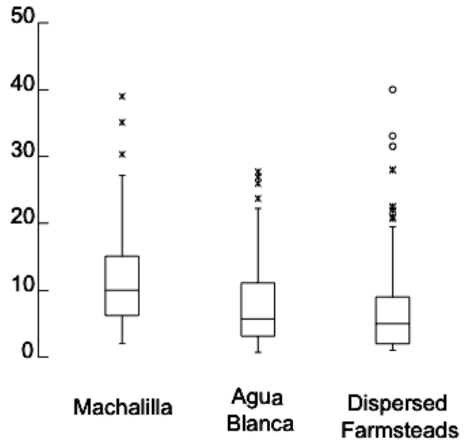

Fig. 6. Box-and-dot plots of Simpson's D scores for every sample within each of the three settlement types

These results strongly point to the nucleated Machalilla settlement as the place with the widest internal variation for archaeological indicators of different activities. However, they do not specifically address what are the types of activities that drive most of this variation. To explore this question, the artifact contents of each Machalilla sample are once again depicted in Fig. 7 as multivariate icons, this time separated into three tool-kits associated with different types of domestic activities.

Fig. 7A depicts the standardized scores of artifacts associated with domestic activities such as food processing, serving, and household maintenance. Figure 7B depicts artifacts associated with craft-production as recognized by Martín (2010b) and Masucci (1995). Figure 7C depicts more elaborate and hard to produce ceramic types, exotic lithic materials such as obsidian, and fragments of ground stone associated with elevated status (such as those of Manteño seats of power) (McEwan 2003). Fig. 7 highlights how most of the variation seen in Machalilla is the result of differences in artifacts associated with craft-production. The domestic kit, whose artifacts are associated with the subsistence economy and daily household maintenance, shows much less variation between samples, suggesting that those activities did not differ as much between households. Finally, domestic units in Machalilla differed the least in what concerns artifacts associated with status, for which very few samples show pronounced variation.

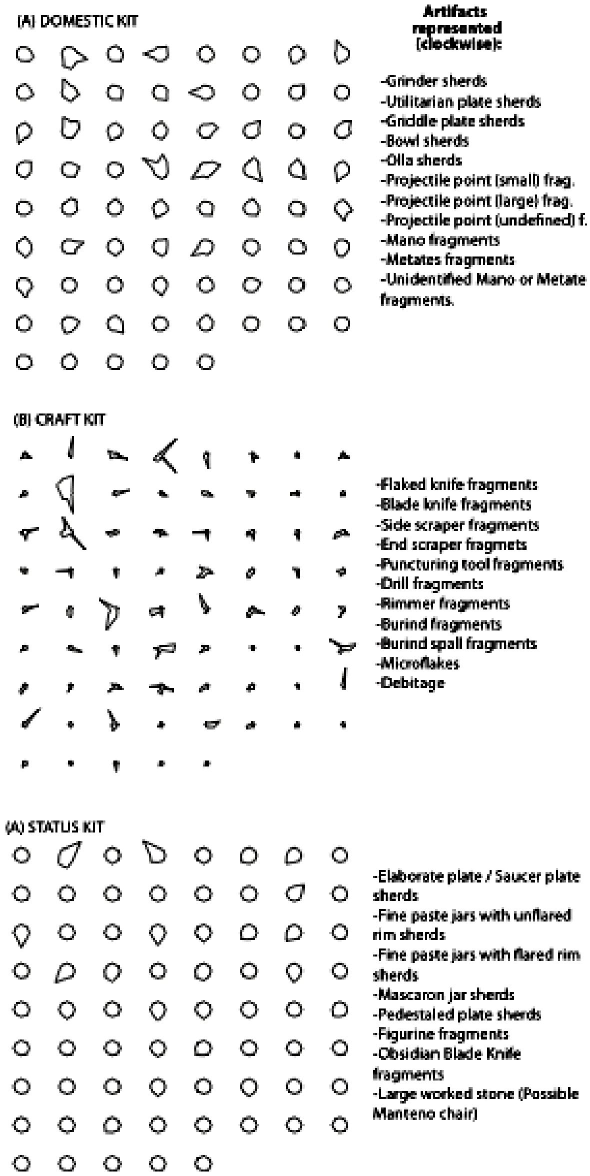

Fig. 7. Iconographic representations of artifact counts (as standardized scores) for each Machalilla sample broken-down into three different household kits. Categories are depicted clockwise beginning at 12 o'clock

CONCLUSIONS

As noted above, research on social complexity has predominantly focused on the need of expansionist polities to tax and administer increasingly larger populations. The inability of chiefly households to parcel authority as their territories grow is often proposed as a likely inhibitor to the formation of more stable political institutions and the long-term viability of the growing political entity. In places like Mesoamerica and central South America, where large bureaucratic societies with full-time canonic, military, and craft specialists developed, it is argued that chiefs were able to segment their power in functionally interdependent ways, preventing local administrators from contesting the authority of the paramount leader. Territorial expansion then continued through many more successive generations and encapsulated much larger populations. Subsequent interdependence in craft production, military roles, or religious institutions took place as the increasingly larger surplus accumulated by these political elites allowed them to finance full-time attached specialists (Costin 1991; Earle 1997). For our discussion, the important element is that under this model functional interdependence is argued to have occurred first within political institutions, which then allowed increases in social complexity elsewhere.

However, the compositional analysis of our chiefly polity in the coast of Ecuador suggests that functional interdependence is already more pronounced in contexts of high population nucleation, even for communities such as those of coastal Ecuador that never developed specialized bureaucratic apparatuses. In the case of coastal Ecuador, nucleation at Machalilla is strongly associated with a maritime substance strategy and craft production for trade (Martín 2010b, 2010c). Archaeologists working in this region have long noted the critical role that the manufacture and trade of shell ornaments and ritual paraphernalia played in the local economy (Currie 1995; Harris *et al.* 2004; Marcos 1977/78; Masucci 1995; Mester 1990; Muse 1989; Zeidler 1991), and for our study area this industry appears as the main culprit driving population nucleation. As the network of interaction available to the residents of Machalilla grew, it seems to have fomented household specialization and interdependence. This does not mean that every household became a full-time specialist of craft activities, but population nucleation appears to have allowed more pronounced degrees of complementarity between craft production activities than those places where households were more dispersed and had smaller networks of interaction.

Demographic environments in which domestic units have access to larger groups of people seem to facilitate specialization of activities and social roles. It is also possible that such inherent demographic factors might help explain why – as Charles Spencer suggests – certain polities were able to institutionalize and segment political authority at critical moments in their expansionist history while others were unable to do so. The data presented here, however, suggests that more interdependent social roles might not necessarily occur first within political institutions and then in religious, military, or (non-subsistence) productive endeavors. Rather, it may be possible that non-institutional factors, such as community demography, simultaneously facilitate specialization in various social spheres. Craft-production seems to be a category that was especially affected by network size in the case of coastal Ecuador.

The analyses carried out here sketch in broad strokes rough correspondences between demography and compositional interdependence for one chiefly society. Much more precise analyses at many more locations are necessary to properly support a correspondence between nucleation and interdependence, and if supported, to bring about a sharper picture of the mechanics of this relationship.

To this end, the distribution and heterogeneity of archaeological indicators can be very useful tools. Analyses of artifact diversity can be focused on additional material indicators not explored here (such as the distribution of ritual paraphernalia to explore the effects of nucleation on ritual organization, for example), which would reveal much about the structural organization of particular social institutions. This type of information can complement more targeted reconstructions of specific households, hopefully offering supplemental information to understand in fuller ways the structure and nature of community composition, as well as what pressured or inhibited changes in its complexity.

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Appendix A

Variables depicted through multivariate icons (clockwise beginning at 12 o'clock)

1	Grinder sherds
2	Elaborate plate / saucer plate sherds
3	Utilitarian plate sherds
4	Griddle plate sherds (often called 'Rallador Manteco')
5	Bowl sherds
6	Olla sherds
7	Jar with flared rim sherds
8	Jar with unflared rim sherds
9	'Mascaron' jar sherds
10	Pedestal plate sherds
11	Figurine fragments
12	Other sherds
13	Preform
14	Flake knife
15	Blade knife (all materials except obsidian)
16	Blade knife (obsidian)

17	Side scraper (raedera)
18	End scraper (raspador)
19	Puncturing tool
20	Drill
21	Rimmer
22	Burin
23	Burin spall
24	Projectile point (small)
25	Projectile point (large)
26	Projectile point (undefined)
27	Core
28	Axe
29	Micro flake
30	Debitage
31	Undefined (likely debitage)
32	Mano
33	Metate
34	Undefined Mano or Metate
35	River stone, small (polishing pebble?)
36	River stone, large
37	Large worked stone (chair, column, or sculpture fragment)
38	Other ground stone
39	Unworked *Spondylus princeps*
40	Unworked *Spondylus calcifer*
41	Unworked *Spondylus sp.*
42	Unworked *Pictada mazatlanica*
43	Unworked *Pteria sterna*
44	Unworked *Arcopsis solida*
45	Unworked *Lyropecten subnodosus*
46	Unworked *Leptopecten tumbezensis*
47	Unworked *Arca pacifica*
48	Unworked *Pseudochama corrugta*
49	Unworked *Ostrea sp.*
50	Unworked *Ostrea tridescens*
51	Unworked *Ostrea fisheri*
52	Unworked *Prothotaca columbiensis*
53	Unworked *Perigplyta multicostata*
54	Unworked *Chama budiana*
55	Unworked *Dosinia ponderosa*

56	Unworked *Corbula ovulata*
57	Unworked *racgucardium procerum*
58	Unworked *Tellina planulata*
59	Unworked *Chione sp.*
60	Unworked *Tucetona strigilata*
61	Unidentified Unworked Bivalve
62	Worked *Spondylus princeps*
63	Worked *Spondylus calcifer*
64	Worked *Spondylus sp.*
65	Worked *Pictada mazatlanica*
66	Worked *Pteria sterna*
67	Unidentified worked Bivalve
68	Unworked *Thais melones*
69	Unworked *Crepidula onyx*
70	Unworked *Thais haemastoma biserialis*
71	Unworked *Thais calloensis*
72	Unworked *Turbo saxosus*
73	Unworked *Tegula verrucosa*
74	Unworked *Conus vittatus*
75	Unworked *Fissurella virescens*
76	Unworked *Cypraea arabicula*
77	Unworked *Nassarius versicolor*
78	Unworked *Natica chemnitzii*
79	Unworked *Natica elenae*
80	Unworked *Acanthina muricata*
81	Unworked *Bursa caelata*
82	Unworked *Pleuroploca princeps*
83	Unworked *Hexaplex ambiguus*
84	Unworked *Hexaplex princeps*
85	Unworked *Malea rigens*
86	Unworked *Phyllonotus brassica*
87	Unworked *Operculos*
88	Unworked *Isognomon recognitus*
89	Unworked *Siphonaria gigas*
90	Unworked *Crucibulum scutellatum*
91	Unworked *Astraea babelis*
92	Unworked *Fasciolaria princeps*
93	Unworked *Purpura pansa*
94	Unworked *Strombus galeatus*

95	Unworked *Strombus peruvianus*
96	Unworked *Vasum caestus*
97	Unworked *Olivella columellaris*
98	Unworked *Cerithium sp.*
99	Unidentified Unworked Gastropod
100	Worked *Strombus galeatus*