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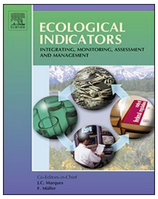

Detecting change in local ecological knowledge: An application of an index of taxonomic distinctness to an ethnoichthyological classification in the Solomon Islands

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ABSTRACT

The global accelerating loss of biodiversity is having immediate repercussions for ecosystems and human wellbeing, particularly in areas where people depend intimately on their natural environment for their livelihoods. Dovetailing this loss is the demise of local/traditional knowledge systems resulting from factors such as changing lifestyle and the transformation of local belief systems. While the importance of local ecological knowledge (LEK) for documentation of biodiversity and environmental change and development of management responses is well established, quantitative tools to analyze and systematically compare LEK are scarce. In this research, we analyze the complexity of local ecological knowledge used by respondents to classify locally-recognized marine species. We do so by applying a modified index of taxonomic distinctness to an ethnoichthyological classification in coastal communities in the Solomon Islands. In addition, we assess simple taxonomic diversity (richness in locally-recognized species names) by comparing taxonomies collected in 1992–1995 and 2014–2015. Results indicate that both endogenous (gender, age) and exogenous (proximity to market) factors have discernible effects on folk taxonomic knowledge in the region, with younger respondents and communities closer to a regional market center displaying a significantly lower richness of local species names. Folk taxonomic distinctness was significantly reduced closer to the regional market. The modified index of taxonomic distinctness applied in this research provides a useful tool to explore facets of local ecological knowledge in addition to simple richness of terms, and to compare across different regions and cultural backgrounds. Understanding changes in LEK is important because such knowledge enables communities who are highly dependent on living natural resources to harvest and manage resources more efficiently and also to detect and react to environmental change.

1. Introduction

The global loss of biodiversity has accelerated rapidly in recent years (Cardinale et al., 2012; Dirzo and Raven, 2003; Dirzo et al., 2014). The current rate of loss has prompted some researchers to argue that the planet may be facing the sixth mass extinction event in its history (Barnosky et al., 2011; Wake and Vredenburg, 2008). Biodiversity plays a critical role in the provision of important ecosystem services, stabilizing ecological processes, and is thus of great importance for the integrity of the world's ecosystems, its biogeochemical cycles, and ultimately the livelihoods of billions of people, particularly those directly dependent on natural resources. The realized importance

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of biodiversity, and of the threats facing it, has spurred research into the link between biodiversity and ecosystem functioning, and into indicators of biological and functional diversity (Cardinale et al., 2012). There is also an ethical dimension, stemming from the argument that other forms of life also have an inherent right to exist, beyond the benefits that they can or cannot provide humanity (Baillie and Butcher, 2012).

The most immediate repercussions of biodiversity loss for human wellbeing are found in areas where people depend intimately on their natural environment for their livelihoods. Overwhelmingly, this tends to be so in non-industrialized regions of the tropical belt, and these regions are frequently characterized as being disproportionally impacted by current trends of environmental degradation (Barlow et al., 2018). This makes them particularly vulnerable to the effects of global environmental change (Dirzo and Raven, 2003). Examples of an extraordinarily intimate connection between humans and their natural environment can be found in the islands of the South Pacific (e.g., Akimichi, 1978). Here, millennia of living in an environment comprised of highly biodiverse ecosystems, particularly adjacent to rich marine environments, and with limited carrying capacity has resulted in a rich legacy of place-specific knowledge. This richness in knowledge is mirrored in high cultural diversity, and traditions of resource use and management are tied closely to the processes and cycles of the environment (Johannes, 1981; Ruddle et al., 1992). Local nomenclature for the natural environment reflects this close connection, expressing a rich local ecological knowledge (LEK) (Ruddle, 1994). For example, the Hawai'ian language is said to distinguish between more than 100 particular types of rain (Kent, 1993). Working with keepers of LEK is increasingly recognized as an important means of documenting biodiversity and environmental change and its causes, as well as achieving improved conservation outcomes (e.g., Warren, 1996; Wilder et al., 2016). There are numerous examples of local ecological knowledge providing researchers with information previously unrecorded in the scientific literature, including on new species or important aspects of species' biology (Johannes, 1981; Narchi et al., 2014).

A particular type of LEK relevant to biodiversity is folk taxonomy. Although they do not capture the extent of phylogenetic information that academic, Linnaean taxonomy contains, folk taxonomies frequently contain detailed information on the habitat, behavior, physiological traits, and human use of a wide range of species (Begossi et al., 2008; Brown, 1984; Hunn, 1982). Thus, a rich folk taxonomy is an important resource enabling communities highly dependent on living natural resources to harvest and manage these more efficiently, but also to detect and react to environmental change. The latter point is illustrated by many case studies, such as Wilder et al.'s (2016) study of the Comcaac people in north-western Mexico. Conversely, a loss of this form of LEK threatens to reduce the adaptive capacity of local communities, increasing their vulnerability to ongoing local and global environmental change (Gómez-Baggethun et al., 2013). Similar to biodiversity, folk taxonomy is rapidly disappearing (Aswani et al., 2018). Changes in lifestyle, economic and cultural globalization, poverty, disappearance of indigenous belief systems and urbanization are among the factors contributing to the demise of traditional knowledge systems (Christie and White, 1997; Gómez-Baggethun et al., 2013).

Research into the loss of folk taxonomy in connection with environmental degradation remains limited to an assessment of the loss of folk taxonomic terminology, but evidence is mounting of its serious implications. This impoverishment is likely to have an impact on biological diversity, as there is increasing evidence that there is a co-occurrence of linguistic and biological diversity in many parts of the world (Gorenflo et al., 2012), and that decrease in one can affect the other (Sutherland, 2003). This problem is being compounded by the "shifting baseline syndrome" (Pauly, 1995), which refers to a situation in which what older people recognized as their natural environment is no longer understood equally by younger people living in new environmental conditions (often in more degraded and resource poor environments). For instance, Turvey et al. (2010) quantitatively studied the rapidly shifting baselines of Yangtze River Fishermen in China to show increasing generational gaps between young and old fishers in their understanding of local species' abundance and distribution over time.

When studying folk taxonomies, focusing on the number of terms alone fails to account for the additional embedded information that classifies species according to locally-known categories such as morphology, taste, behavior, or habitat (Cohen et al., 2014; Ono and Addison, 2009; Ruddle, 1994). However, this information is particularly important for the ability to understand and detect ecological processes and react to changes therein. Furthermore, complementary information regarding habitat, ecology or capture methods is likely to become lost more easily in response to changes in lifestyle (e.g. fishing) than names of species (May, 2005). Thus, indicators that account for these additional layers of information are more likely to detect subtle changes in LEK than those that focus only on the type and number of different names. However, indicators that quantify the complexity of LEK and allow for a comparison across taxonomies and different cultural settings are currently lacking. In this paper, we apply a modified index of taxonomic distinctness to an ethnoichthyological classification in a number of coastal communities in the Solomon Islands in order to capture the complexity of additional information used by respondents to classify locally-recognized species. In addition, we assessed simple taxonomic diversity, i.e. richness in locally-recognized species names, and used this to compare taxonomies collected in 1992–1995 and 2014–2015. Specifically, we examined differences in folk taxonomic knowledge between age and gender groups and at different levels of economic development (i.e., distance to market), and compared the aspects of change captured by indices of taxonomic distinctness and taxonomic diversity.

2. Materials and methods

2.1. Field site

The research was conducted in Melanesia, which encompasses the nations of Papua New Guinea, the Solomon Islands, Vanuatu, New Caledonia, and Fiji, and is well known for its cultural diversity and rich systems of ecological knowledge (e.g., Hviding, 1996; Johannes, 1993; Veitayaki, 2002). Specifically, we conducted research in the Solomon Islands, where knowledge of marine systems and associated habitats and species is particularly well developed (e.g., Akimichi, 1978; Hviding, 2005). While marine ecosystems are still healthy in the region, they are becoming increasingly disturbed by human activities. Overexploitation of marine resources, decreasing water quality caused by sedimentation linked to terrestrial run-off (resulting from logging and poor agricultural practices), and climate change-related processes (e.g., coral reef bleaching) are the primary drivers of this transformation (e.g., Brown et al., 2017; Halpern et al., 2013; Hughes et al., 2003). In the past, local communities had managed their marine ecosystems through intricate systems of local marine governance, such as sea tenure, and complex systems of ecological knowledge that informed management decisions (Johannes, 1978). However, as elsewhere, these systems have either disappeared or have been highly degraded in many parts of this region due to socio-cultural and economic changes (Christie and White, 1997). This, combined with often ineffective national government resource management plans, has led to the degradation of many near-shore marine resources in the region (Albert et al., 2015; Ruddle and Hickey, 2008).

The specific research site was on the island of New Georgia in the Western Solomon Islands, which is surrounded by large lagoon systems including the Marovo, Nono, Roviana, and Vonavona lagoons that are rich in marine biodiversity (Fig. 1) (Aswani and Albert, 2015; Hviding, 2006). The Roviana Lagoon study site extends from Lambete in Munda to Kalena Bay at the end of the lagoon, and is composed by a number of

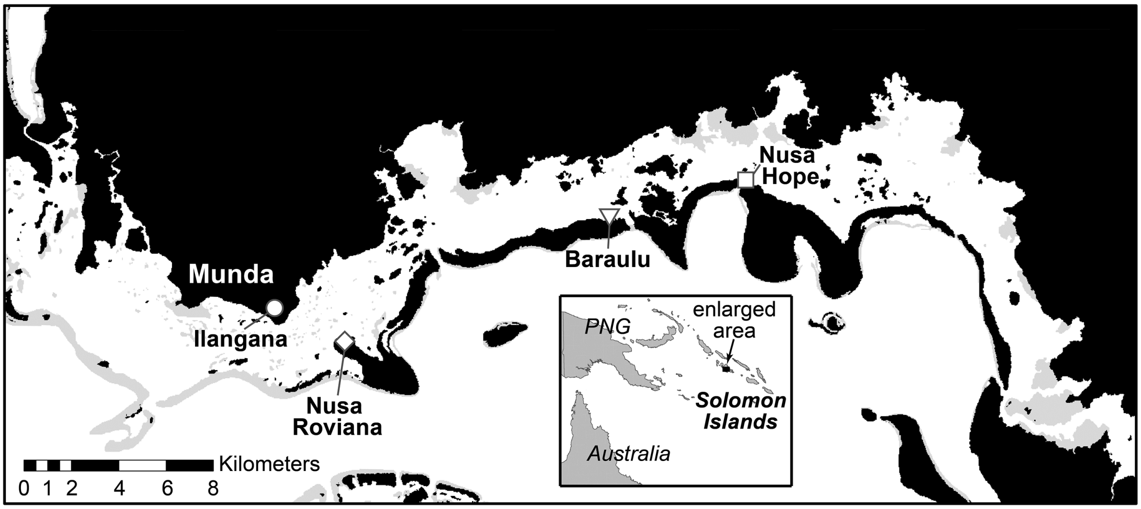

Fig. 1. Map of the study area and research sites (indicated by white symbols). The location within wider Melanesia is shown on the inset map.

raised coral islands characterized by rugged and notched limestone that enclose a range of marine habitats including mangroves, seagrass beds, and coral reefs, among others (Stanton and Bell, 1969). The majority of the more than 15,000 inhabitants in the Roviana and Vonavona lagoons are Roviana speakers and hence are closely related socially and culturally. In recent years, traditional centralized chiefly authority has been largely eroded, and remaining elders and community leaders attempt to control the use of and access to marine resources within their traditional territories as they increasingly face the socio-economic pressure and encroachment of Asian resource extraction multinationals (Aswani, 2019). Locally, while people engage in multiple subsistence and small-scale economic activities (e.g., marketing of vegetables), the livelihoods of Roviana people are increasingly being threatened by the continued degradation of marine habitats resulting from activities such as the intense exploitation of commercial species like bêche-de-mer and sedimentation from run-off linked to destructive land-based practices such as large-scale logging (e.g., Albert et al., 2011). These processes, in tandem with other impacts related to climate change, are increasingly degrading marine and terrestrial habitats and endangering the present and future livelihoods of Roviana people.

In terms of local marine knowledge, Roviana fishers have (1) spatially detailed mental maps of the seascape; (2) a sophisticated system of marine organism and habitat classification, use, and allocation; (3) the capacity to recognize local ecological transformations and associated impacts on habitat structure, species composition, and spatio-temporal extent of biological events of significance; and (4) an understanding of larger ecological processes such as the presence of vulnerable life stages and inter-connectedness among species and associated habitats (Aswani and Albert, 2015; Aswani and Lauer, 2006, 2014; Hamilton and Walter, 1999). Today this intergenerational knowledge is not only hybridized by the introduction of novel ideas and customs, but it is also increasingly being eroded by rapid socio-cultural and economic changes (Aswani and Albert, 2015), further threatening peoples' capacity to sustainably exploit the environment.

2.2. Data collection

Originally, local ecological knowledge (LEK) of marine environments and associated organisms was documented through extensive participation in fishing expeditions and interviews with fishers between 1992 and 1995, albeit local ecological information was collected intermittently till 2012. For the baseline data, focus groups with young, middle-aged, and elderly men and women from the region, who were selected based on local referral for their knowledge of the marine environment, were conducted during this period, as well as open-ended, semi-structured, and structured interviews with key informants to document LEK (for further details, see Aswani, 1997). During these interviews, people were asked to distinguish: (1) name and composition of local marine habitats; (2) species of fish, shellfish, crustaceans and other marine organisms found in each habitat type, and their taxonomic groupings; (3) seasonal changes in the availability of different species found within each marine habitat; (4) distinctive spatio-temporal events such as grouper spawning aggregations; (5) climatic conditions (e.g., weather, or phase of tidal and lunar cycles) and their impacts on marine habitats and associated marine organisms; and (6) local fishing methods employed in each identified marine habitat. Then, this marine local ecological knowledge was cross-referenced with scientific materials for formal identification. For instance, many fish species were identified using photographs and comparing them with those in Masuda et al. (1984), Munro (1967), and Randall et al. (1990), and through specimen collections. This information provided a baseline folk taxonomy that served as the background for this study. While some locally-recognized species corresponded to multiple western scientific species, only for very few it was not possible to identify a corresponding western scientific species name (see Table A.1).

To assess the effects of gender, age and distance to market on ecological knowledge, information on current folk taxonomies was collected in 2014 and 2015 from four communities in the Roviana Lagoon of Western Province, Solomon Islands, along a gradient of distance to the regional market and transport center, Munda, which includes an airstrip and has direct flights to the national capital Honiara (Fig. 1). From west to east—those in the west being closer to the provincial town Munda—the communities Ilangana, Nusa Roviana, Baraulu, and Nusa Hope were studied. Ilangana essentially is an eastern neighborhood of Munda, within walking distance of the market area in Munda's center (Lambete Government Station). The other communities all are reachable only by boat; from Nusa Roviana it takes about 15 mins to reach Munda by canoe, while Baraulu and Nusa Hope are more than half an hour away even using an outboard engine. Transport to Munda by boat generally occurs via the protected waters of the lagoon, rather than over the deep waters outside the barrier islands. Overall, geographic distance to Munda is an adequate proxy for travel times and ease of access for each community to medical and commercial activities. At each site eight focus groups were held, representing four age groups (13–19, 20–35, 36–55 and > 55 years) divided by gender. Participants in each age group were selected by each village leadership to participate in the focus groups under the premise of being a "competent marine harvester" for their age group and gender. Participants were asked to free-list all local names of marine species (particularly fishes) known to them, thus allowing each respondent to list as many responses as they wanted. Then, they were instructed to assign the free-listed names into broader categories through pile sorting if possible, which represented local taxonomic groupings, and provide information on the characteristics underlying classification into each of the broader categories. To assess what kind of domains of knowledge respondents drew on in their classification, the descriptors used to characterize categories were assigned to one of five domains: taxonomic (e.g. if respondents used a generic term such as *mara* [carangids] to describe a group), appearance (i.e. for information on morphology, color or smell), behavior (e.g. schooling), habitat (e.g. deep water, seagrass), or utilitarian characteristics (e.g. bait, gear used to catch a species, or way of preparation). The listed names were then compared to the baseline data collected more than twenty years earlier. To account for the fact that local classifications do not necessarily align with Linnaean taxonomy, all vertebrate species identified by the respondents as ‘marine fish’ except reptiles were recorded (i.e. including cetaceans, dugongs and freshwater species occasionally found in the lagoon, but excluding e.g. jellyfish or cephalopods). All interviews and focus groups followed established principles of prior informed consent, explaining the nature and goals of research to participants, informing them of their right to withdraw from interviews, and asking for consent before proceeding with the interviews.

2.3. Data analysis

Data from each respondent group were compared among groups and with a list of local species names collected in 1992–1995 by similarity clustering and nonmetric Multi-Dimensional Scaling (nMDS) based on Bray-Curtis similarities of untransformed data. This approach calculates degrees of similarity between different samples based on the amount of overlap in species among samples. To test for differences in the composition of folk taxonomies between male and female groups, a one-way permutational Analysis of Similarity (ANOSIM) was performed on Bray-Curtis similarity data (Clarke and Green, 1988). As the factors ‘community’ and ‘age’ may have had interactive effects on folk taxonomies, they were tested in a two-way crossed ANOSIM, so that age groups were compared within each community, and communities within each age group (Clarke, 1993). SIMPER analyses were used to assess the amount of similarity within factor groups and dissimilarity among factor groups, as well as to identify species contributing particularly to within-group similarity or among-group dissimilarity (Clarke, 1993). All multivariate analyses were performed using the program PRIMER 7.0.13 (Clarke and Gorley, 2015). In addition, a modified index of mean taxonomic distinctness assessing the complexity of each group‘s taxonomic inventory was calculated (Clarke and Warwick, 1998), which incorporates information on groups in the taxa identified by the respondents. The index assesses the complexity of this emic (i.e. indigenously conceptualized) system of grouping by pairwise comparisons of all taxa in a sample, generating ‘branches’ among the taxa the length of which corresponds to the number of unique descriptors among a given pair of taxa, and measuring the mean branch lengths between taxa for the entire sample.

The original index described by Clarke and Warwick (1998) was developed for taxonomic data conforming to Linnaean classification, which has two properties that are not necessarily found in folk taxonomies: categories possess an inherent hierarchy (i.e. species $<$ genera $<$ families $<$ order) and are unambiguous (i.e., one genus of fish can only be associated with one particular family). While a hierarchical structure seems to underlie many systems of folk biological classification (Berlin et al., 1973), not all locally-recognized taxa may be classified by the same number of hierarchical descriptors, preventing the construction of ‘taxonomic trees’ (which in Linnaean classification contain information on evolutionary descent and relatedness). In folk taxonomies, clear divisions between abstract groupings may be of little relevance (Malm, 2010). Rather, folk taxonomies may assign species to different categories with partially overlapping characteristics that relate to a range of aspects such as haptics, taste, behavior, habitat or fishing gear (e.g., elongate reef fish which are caught by handline and have firm flesh). These characteristics do not have an inherent hierarchy, but comprise knowledge that is highly relevant with regards a taxon’s use and management, and may differ between social groups due to the way in which knowledge is acquired and transmitted (Ruddle and Davis, 2013). In order to be able to analyze and compare data that do not conform to these two properties of Linnaean taxonomy, we developed a modified index of mean folk taxonomic distinctness, Δ_{folk}:

$$\Delta_{folk} = \left[\sum\sum\nolimits_{i<j} \frac{\nu_{ij}}{2}\right] / [n(n-1)/2]$$

where ν_{ij} refers to the number of unique characteristics, including species names, common to a given pair of species i and j, and n is the total number of distinct species in the sample.

This modified index allows for taxonomies that comprise categories with different numbers of defining characteristics. It accounts for both the number of characteristics describing each individual species and the number of characteristics unique to each species in a species pair, i.e. two measures of the level of detail in a folk taxonomy. In addition to the mean taxonomic distinctness, standard deviations of the means for each respondent group were calculated. These provide an indication of the heterogeneity in amount of descriptors given for each category, i.e., if each category of a respondent group is characterized by the same amount of descriptors, the SD of Δ_{folk} is lower than if some categories are characterized with few and others with a high amount of descriptors.

The numbers of distinct species identified by each focus group were compared between genders and among age groups and communities through a comparison of means in R (R Core Team, 2019), as were differences in folk taxonomic distinctness among the groups. To account for a potential interaction of the effect of age and community (e.g., younger respondents could be affected more strongly by the gradient of modern lifestyles represented by the different communities than older respondents), the interactive term age*community was included as an additional explanatory factor. Both respective full models of comparisons of means were reduced to their minimal adequate models using stepwise backward model selection, with only significant terms retained under the condition that the minimal adequate model would not represent the data significantly worse than the full model ($<$ 2.0 difference in Akaike information criterion, AIC, and no significantly different variance tables of the minimal compared to the respective full models). To assess how folk taxonomic distinctness related to the number of local species names given by the different respondent groups, the relationship of Δ_{folk} and number of local species names was assessed using Spearman’s rank correlation in R. All univariate analysis steps are documented in https://github.com/MoritzSt/Ethnoichthyological-Classification.

3. Results

3.1. Species number and diversity

A total of 456 local species names were recorded over the more than two decades of research (doi of raw data: https://doi.org/10.1594/PANGAEA.918696). These included 279 names compiled during an initial comprehensive survey in the 1990s (52 of which were not recorded again in the later survey) and 177 names newly recorded in 2014–15 (Table A.1 and A.2). In a few instances, the latter comprised generic terms to describe higher taxonomic groups (usually at the genus or family level) for which a finer resolution had been recorded in the previous survey. This increasing use of more generic terms may indicate a loss of detailed folk taxonomic knowledge by particular groups of respondents (Fig. 2). The number of local species names listed by respondent groups ranged from 25 to 168. The final minimal adequate model for comparison of means was significant as a whole ($p < 0.001$).

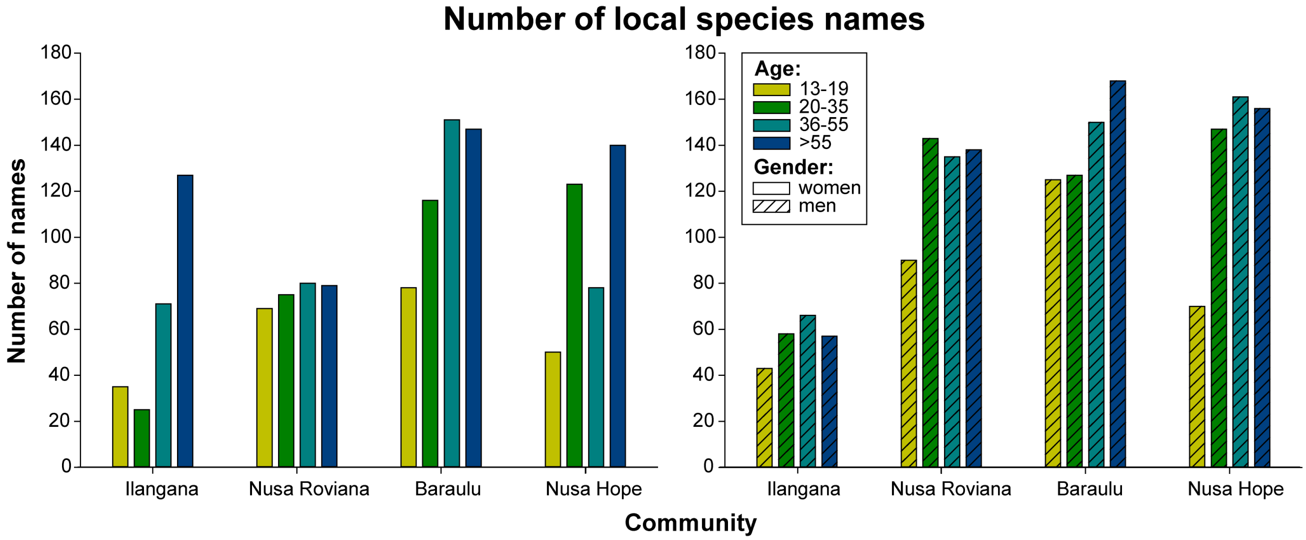

Fig. 2. Number of locally-identified species names among age groups for women (left) and men (right) across the four communities. Species numbers differed significantly between genders, age groups and communities (c.f. results).

Table 1
Results of the respective minimal adequate models for comparison of means of number of local species names (a) and mean folk taxonomic distinctness (b). As only significant terms are included in minimal adequate models, results for non-significant terms are not shown. Asterisks indicate level of significance: *** < 0.001; ** < 0.01; * < 0.05.

a Number of local names					
	df	**SS**	**Mean Sq**	**F value**	**p**
gender	1	4753	4753	8.182	0.009 **
age	3	13,710	4570	7.867	< 0.001 ***
community	3	22,994	7665	13.194	< 0.001 ***
residuals	24	13,942	581		
b Mean taxonomic distinctness					
	df	**SS**	**Mean Sq**	**F value**	**p**
community	3	2.616	0.872	4.248	0.043 *
residuals	28	5.748	0.205		

The number of species names differed significantly by gender and among age groups and communities, while the interaction of age and community was not significant (Table 1a). The number of species mentioned was higher for groups of males than females, and increased both with respondents' age and with distance from Munda market (Fig. 2).

3.2. Taxonomic groupings and distinctiveness

Taxonomic inventories of focus groups formed similarity clusters that broadly reflect geographic distribution of the communities, with inventories of older groups and remote communities being most similar to the comprehensive species inventory for the lagoon developed in 1992–95 (Fig. 3). Three female groups of respondents, each from different ages and communities, showed particularly distinct taxonomic inventories. Overall however, the composition of taxonomic inventories did not differ according to gender, but was significantly influenced by age (two-way crossed ANOSIM, $R = 0.293$, $p = 0.004$) and community (two-way crossed ANOSIM, $R = 0.505$, $p = 0.001$). Pairwise tests showed that significant differences existed between age groups 13–19 and 20–35 ($p = 0.037$) as well as 13–19 and > 55 ($p = 0.012$). Among communities, differences existed between Ilangana and Baraulu ($p = 0.012$), Ilangana and Nusa Hope ($p = 0.012$), and Nusa Roviana and Baraulu ($p = 0.012$). Groups of male respondents showed a slightly higher average similarity than groups of female respondents (SIMPER, 51.73% and 43.40%, respectively). Differences between male and female respondents existed mostly in particular shark, grouper and tuna species, which were more frequently mentioned by male groups. While there were six names of species listed by all male groups, no local species were common to all female groups (Table A.3). Among age groups, the highest average similarity was observed among the youngest respondents (SIMPER, 62.52%), while the other age groups were similar in their average similarity (around 55%, Table A.4).

Differences between the youngest and older age groups existed in locally-recognized species mentioned by most or all older respondents, but not at all or only rarely by younger ones, such as *gomo* (Bigeye Tuna), *hirapa* (Sailfin Snapper), and *kitakita* (juvenile Bumphead Parrotfish; Table A.4). Among communities, the highest internal similarity of folk taxonomies was observed in Baraulu (SIMPER, 64.55%), while the other communities had similar internal similarities between 53 and 55% (Table A.4). Differences between folk taxonomies of inner-lagoon communities (Baraulu and Nusa Hope) and those closer to Munda (Ilangana and Nusa Roviana) existed in several species listed by groups from the former, but not the latter communities, such as *pipilaka* (juvenile Queenfish), *mata pou* (Fringe-fin trevally) and *sego* (Indo-Pacific tarpon; Table A.4).

Mean folk taxonomic distinctness (Δ_{folk}) ranged from 1.77 to 4.43 (Fig. 4). The number of local species names and Δ_{folk} for different groups of respondents showed indications of a positive (albeit insignificant) relationship (Spearman's rank correlation, $\varrho = 0.320$, $p = 0.074$), indicating that both parameters show a similar trend on a fundamental level, but that each also captures different dimensions of the examined folk taxonomies (Fig. A.1). The comparison between groups by gender, age, community and combination of the latter two factors resulted in a minimal adequate linear model which was significant as a whole ($p = 0.014$). Community was the only significant driver of folk taxonomic complexity (Table 1b), with values for Ilangana, the community closest to the market in Munda, being lower than those of other communities (Fig. 4).

There was considerable heterogeneity in the amount of characteristic descriptors used by respondent groups to describe the groups into which they classified species (Table 2; doi of raw data: https://doi.org/10.1594/PANGAEA.918711), ranging from 4 to as many as 58. Old men from Baraulu were the group with the highest number of species names, mean folk taxonomic distinctness, and number of descriptors. This group also had the highest standard deviation in Δ_{folk}, reflecting the fact that their classification of species ranged from a simple free list with the only common characteristic being 'marine fish', to a group comprising mullets, tarpon, Sixfinger threadfin and milkfish, which was

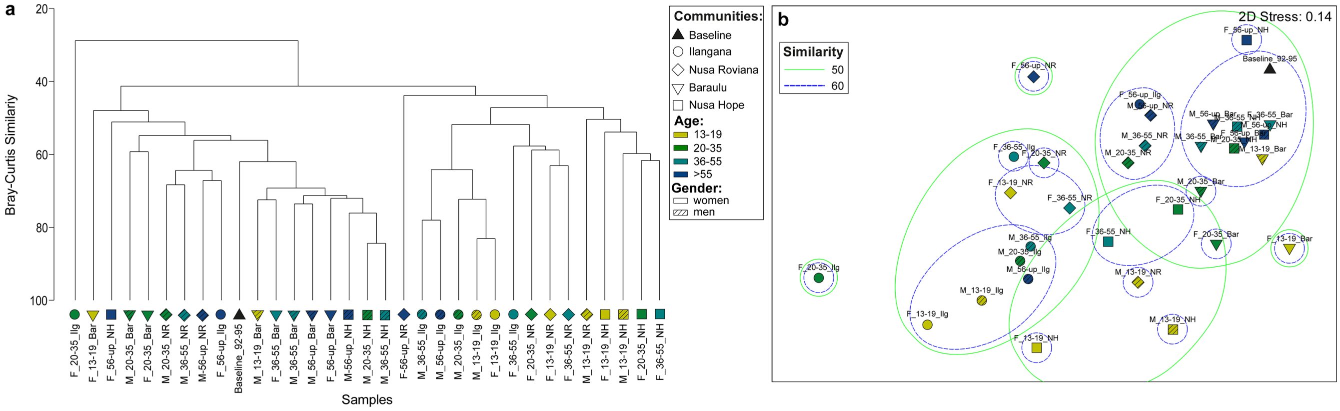

Fig. 3. Clustering and multidimensional scaling of focus group species lists based on Bray-Curtis similarities among samples. For comparison, a complete lagoon-wide species inventory compiled in 1992–1995 is included (black triangle).

characterized with seven descriptors ('fish', 'similar skin', 'swim in groups', 'same prey', 'don't sleep', 'no teeth' and 'can't be fished with a fishing line'). With regards to the kinds of descriptors used by respondents (doi of raw data: https://doi.org/10.1594/PANGAEA.918712), there were few discernible trends (Table 2). None of the respondents from Ilangana used any utilitarian descriptors, while groups of both genders from all other communities did. Old men from Baraulu used an exceptionally high number of descriptors related to behavior and appearance. More descriptors of the latter kind were only used by teenage male respondents from Nusa Roviana. These two groups, and female teenagers from Nusa Hope, were the only groups mostly using descriptors related to appearance. Overall, taxonomic descriptors (i.e. classifying species with apparently related ones, similar to a Linnaean taxonomy) made up nearly half of the descriptors used, followed by appearance (around 25%) and habitat. Utilitarian and behavioral descriptors each made up < 10% overall.

4. Discussion

The results of this study underline the potential of local ecological knowledge (LEK) to contribute to the documentation of biodiversity and information on species' ecology, with a high overlap between local and academic, Linnaean taxonomies. The folk taxonomy of Roviana communities is similar to others in Melanesia and Southeast Asia (Foale, 1998; Hviding, 2005; May, 2005), with about 50 more species names recorded in the 2014–15 study than for the nearby Marovo Lagoon (Hviding, 2005) and West Nggela (Foale, 1998) areas. Etymologically and structurally, the taxonomy follows the general principles identified by Berlin et al. (1973). Primary and secondary lexemes are used to denote groups (in most cases corresponding to Linnaean genera or families) and locally-recognized species, respectively. Similar to other ichthyofaunal folk taxonomies (Begossi et al., 2008; Foale, 1998; May, 2005), primary lexemes usually have no translation, while secondary lexemes consist of terms for e.g. external appearance, habitat, or behavior.

Analyses based on number of names revealed influences of gender, age and distance to a regional center on richness of the local folk taxonomy, confirming previous observations (Aswani and Albert, 2015; Christie and White, 1997; Ruddle, 1994). The "shifting baseline syndrome", or intergenerational loss of ecological knowledge, has been observed in traditional fishing communities throughout the world (e.g., Ainsworth, 2011; Ainsworth et al., 2008; Bunce et al., 2008; Turvey et al., 2010). Older respondents in remote communities recalled folk taxonomic inventories close to an overall lagoon-wide inventory developed two decades earlier. Rationales and characteristics underlying local classification of taxa into groups, which comprised generic, non-

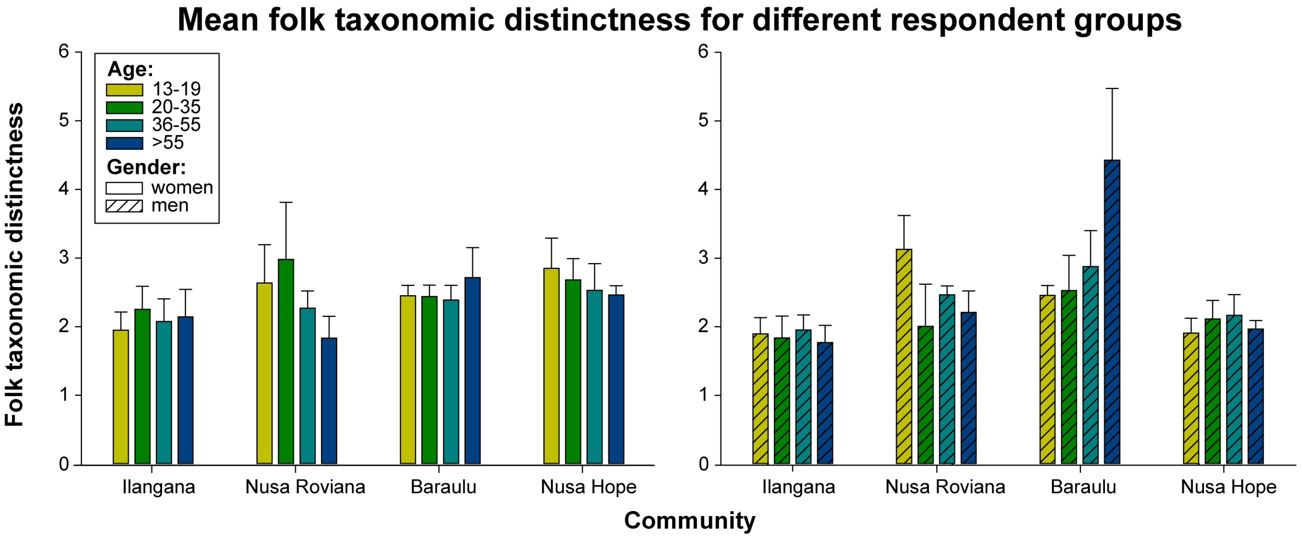

Fig. 4. Mean taxonomic distinctness of folk taxonomies among age groups for women (left) and men (right) across the four communities and age groups. Error bars indicate standard deviations and provide an indication of heterogeneity in the amount of descriptors for groups of species (see methods). Outcomes were significantly related to community (c.f. results), with values lower in Ilangana, located closest to the regional market in Munda.

Table 2
Number of descriptors and categories (i.e. unique combinations of descriptors) used by respondent groups to classify locally-recognized species, and number of descriptors belonging to each of five domains of knowledge (i.e. taxonomic, appearance, behavior, habitat and utilitarian; see Methods for details). In many instances, the same descriptors were used by multiple groups of respondents; the totals thus do not reflect unique terms.

Group*	Descriptors	Categories	Taxonomic	Appearance	Behavioral	Habitat	Utilitarian
F_13-19_Ilg	10	11	2	0	0	8	0
F_20-35_Ilg	16	18	8	2	0	6	0
F_36-55_Ilg	5	7	2	0	0	3	0
F_56-up_Ilg	11	23	4	1	0	6	0
M_13-19_Ilg	7	8	3	0	1	3	0
M_20-35_Ilg	6	6	6	0	0	0	0
M_36-55_Ilg	13	14	8	2	0	3	0
M_56-up_Ilg	4	4	4	0	0	0	0
F_13-19_NR	11	21	3	3	1	0	4
F_20-35_NR	19	34	8	2	2	6	1
F_36-55_NR	6	5	2	1	0	3	0
F_56-up_NR	6	6	4	2	0	0	0
M_13-19_NR	35	22	2	29	3	0	1
M_20-35_NR	22	25	4	2	4	11	1
M_36-55_NR	20	19	19	1	0	0	0
M_56-up_NR	17	17	14	1	0	1	1
F_13-19_Bar	11	10	7	3	0	1	0
F_20-35_Bar	12	11	11	0	1	0	0
F_36-55_Bar	15	15	10	3	0	1	1
F_56-up_Bar	17	13	8	6	0	1	2
M_13-19_Bar	14	13	8	4	0	1	1
M_20-35_Bar	25	18	17	7	1	0	0
M_36-55_Bar	15	44	1	4	3	5	2
M_56-up_Bar	58	30	3	22	19	5	9
F_13-19_NH	19	15	1	10	2	5	1
F_20-35_NH	19	18	10	4	1	1	3
F_36-55_NH	16	15	4	2	0	10	0
F_56-up_NH	15	14	11	3	0	0	1
M_13-19_NH	5	6	2	0	0	0	3
M_20-35_NH	14	13	7	3	0	2	2
M_36-55_NH	16	16	9	2	0	2	3
M_56-up_NH	17	17	11	4	0	1	1
Total			213	123	38	85	37
Percent			42.9	24.8	7.66	17.1	7.46

*Codes indicate gender (male/female), age class, and community (Ilg = Ilangana, NR = Nusa Roviana, Bar = Baraulu, NH = Nusa Hope).

translatable terms for particular groups at the genus or family level or higher-level “life-forms” (Berlin et al., 1973) or were related to appearance, behavior, or utilitarian characteristics, were similar to other ichthyofaunal folk taxonomies (Begossi et al., 2008; Foale, 1998). The index of mean folk taxonomic distinctness revealed that complexity of even the species-poorer taxonomies of younger respondents was similar to that of older respondents, but the community closest to the regional economic center had a significantly less complex inventory, indicating the potential loss of critical ecological knowledge. While similar levels of complexity across the groups were identified (similar Taxonomic Distinctness), except for Ilangana versus other communities, this does not account for differences in how categorization is done across groups (e.g. some might group by taste/look, others by habitat etc.). People in Ilangana tend to spend less time fishing on average than the other three research communities (see fishing time allocation results for the “Munda Area” [which is inclusive of Ilangana] in Aswani 1997). This could explain, in part, the acceleration of knowledge loss, as integration to markets often leads to the consumption of processed foods and to a decrease in subsistence activities (e.g., Aswani et al., 2018). Fishing knowledge is intimately intertwined with daily practice of fishers, and if that knowledge is not used regularly it can be prone to loss—‘use it or lose it.’ Also, people in Ilangana are closer to markets and thus more integrated into a monetized economy and better connected to other information networks (tourism, internet, television, etc.). Proximity to a market center can thus affect indigenous knowledge in multiple ways, the exact role of each it is not possible to differentiate in the current study. Acculturation due to exposure to a market economy and new information networks can result in loss of local ecological knowledge, as new forms of knowledge take on more importance. Similarly, access to goods that substitute natural products can lead to reduced ecological knowledge (Godoy et al., 2005). A systematic literature review has found evidence of decreased fishing activity and a preference for foods other than fresh fish with increasing levels of urbanization in several Pacific countries and territories (Charlton et al., 2016). However, increased integration into a market economy can also increase knowledge of certain species if these become particularly relevant, leading to a transformation, rather than loss, of local ecological knowledge (Guest, 2002). One potential effect of a commodification of fishery resources and a shift from ‘traditional’ subsistence fishing to a targeting of species for sale is a focus on particular species and reduced diversity of frequently-targeted species, which can result in diminished knowledge of a large range of species. The trends observed here among communities in a relatively small area, within the same cultural group, can be seen across societies and cultural groups as well. Societies with a reduced direct dependence on natural resources, concomitant with higher economic development, have been shown to display reduced levels of ecological knowledge (Pilgrim et al., 2008).

There are some caveats to the results presented in this paper. The original approach was to minimize prompting in terms of descriptors, as our interest was in understanding the effects of gender, age, and distance to markets on ethnoichthyological knowledge and taxonomic identification. Given logistical and time constrains, this research necessitated smaller focus groups, which increased the chance that the rationales for emic groupings were not fully described and that the given descriptors were more heterogeneous among sampled groups. This, for instance, contrasts with the approach by Begossi et al. (2008), in which categories of descriptors were given *a priori* by the researchers, leading to results that were more uniform across respondents, and it may have been the reason why there were few discernible trends with regards to kinds of descriptors used by respondents. In Begossi et al. (2008) respondents used habitat, diet, morphology and (secondarily) behavior for taxonomic groupings, whereas in the Roviana case 'habitat' is used less in classification, in favor of using 'morphology' and 'use' as a an emic grouping logic. Characteristics related to use are not extensively described in Begossi et al. (2008), but this may be a result of the researchers pre-defining types of characteristics and categories in that study. In sum, the approach used here is suitable for assessments based only on species names (e.g., number, similarity), but for fully understanding taxonomic complexity, a more uniform approach would have perhaps been more suitable, such as developing regional inventories with high number of respondents and several focus groups for cross-checking each community's results. Furthermore, the observed values for Baraulu (high internal similarity among respondent groups in species names and descriptors, high species numbers, similarity of the more recent data to the 1992–95 list) may partially reflect the long history of research in that community. This is a caveat of the chosen approach, and underlines the importance of selection of respondents in the design of studies on folk taxonomies (Davis and Ruddle, 2010), but a comparison of the values of the communities nearest to and furthest away from Munda (Ilangana and Nusa Hope, respectively) indicate that the observed trends exist irrespective of the history of research at Baraulu. Another point is that species identification based on identification of photographs is not always accurate, as demonstrated by Hamilton and Walter (1999) for a study in Roviana, in which about 1/4 of species listed there were identified differently when using photographs (mostly at species but sometimes at genus level). This underlines that ethnoichthyological research needs to treat LEK carefully, particularly when basing conservation action on the identity of particular species (see e.g. Hamilton et al., 2012). The modified indicator of taxonomic distinctness applied here was developed specifically to assess the complexity of emic classification among different respondent groups, as we were more interested in the rationale and information underlying classification rather than an assessment of the meaning of folk names (e.g., Foale, 1998; May, 2005) or a construction of complete taxonomic trees. However, provided comprehensive information on the different levels of folk taxonomies can be obtained (c.f. Berlin, 1992), the modified index we developed could be applied for comparisons among different folk taxonomies in a similar way the original index of taxonomic distinctness was applied to samples of biological communities (Clarke and Warwick, 1998, 1999). It can thus serve as a systematic methodology for the quantitative analysis and comparison of LEK across communities and different cultural contexts, which is urgently needed (Davis and Ruddle, 2010) but missing to date.

Another important aspect of this research is to acknowledge that while the impoverishment of LEK may be occurring at a general scale there are other forces at play including the creation and hybridization of LEK. For instance, some names from the 1992–1995 list were not encountered anymore, and respondents were using more generic (single) terms at the genus level (i.e. primary lexemes) compared to more complex species-specific terms (i.e. secondary lexemes) used in the early 1990s. Use of more general, primary lexemes may also indicate a change in abundance (Ono and Addison, 2009) or importance (Foale, 1998; Hviding, 2006; May, 2005) of species, as species of low local use (such as butterflyfishes or damselfishes) are often lumped together and described with generic terms. New names were often derived from pidgin; changes in spelling or new names appeared in the new ethnoichthyological lists reflecting the ongoing evolution of local terminology and language.

The present results paint a more complex picture of emic classification and provide some support for both reasons for the nature of ethnobiological classification postulated by Berlin (1992). The significantly lower number of local species names given by younger respondent groups as well as in communities closer to Munda, which fish less extensively than communities further in the lagoon, seem to reflect a *utilitarian* driver of folk taxonomy. Similarly, the low number of local names for speciose but little-utilized groups such as pomacentrids and chaetodonts, contrasting with a high number of local names for groups of prime fishery targets such as carangids and serranids, points to utilitarianism shaping folk taxonomies. For instance, as in Linnaean taxonomy, Roviana folk taxonomies are very complex for highly targeted groups such as *mara* (Carangids) and *pazara* (Serranids). These comprise 26 and 24 locally-recognized species, respectively, differentiated to great extent with the use of secondary, binomial (or sometimes trinomial) lexemes. This is also reported for other areas of the Solomons (Foale, 1998; Hviding, 2006), with Hviding (2006) reporting the local classification at the species level of 35 species of *mara* and 21 species of *pazara*. Similarly, in folk taxonomies of reef fish elsewhere, non-target species (e.g. damselfish) are not differentiated below primary lexeme denoting a generic level, while important target species (e.g. Carangidae, Lutjanidae) are classified into more than a dozen locally-recognized species (e.g., Lobel, 1978; May, 2005). This emphasis also corroborates the conclusions of an early review of principles of taxonomies by Raven and colleagues, who observed that locally-recognized taxonomic groups with more than 20 members "inevitably" signify groups of major local importance (Raven et al., 1971). On the other hand, the similar levels of taxonomic complexity among young and old respondents and between male and female respondents, shown by the lack of significant differences in mean folk taxonomic distinctness, underline that there is some inherent *idealistic* desire to give order to the natural world by the means of folk taxonomy. The only factor significantly affecting taxonomic complexity was 'community', with lower values closest to Munda – when compared with the results for number of local species names, this indicates that complexity of local classification apparently is less strongly affected by changes in lifestyle than taxonomic richness, and is reduced only in a community forming part of a larger, *peri*-urban center.

5. Conclusion

Our results indicate that both endogenous (gender, age) and exogenous (proximity to market) factors have discernible effects on folk taxonomic knowledge in Roviana Lagoon, in line with trends observed elsewhere. The modified index of taxonomic distinctness applied here, while having limitations that need to be considered, proved to be a useful tool to explore additional facets of local ecological knowledge, and has the potential to allow for quantitative comparison of folk taxonomies from different regions and cultural backgrounds even if they are not directly translatable into Linnaean nomenclature (Cohen et al., 2014; Davis and Ruddle, 2010). As pointed out above, the use of small focus groups to elicit local rationales and characteristics underlying classification of locally-recognized species can yield heterogeneous results and needs careful preparation and moderation. Binomial (or sometimes trinomial) lexemes often contain detailed information on habitat, morphology or behavior (Foale, 1998). As these terms are more 'fixed', they are likely a better source of local ecological information than trying to explore emic groupings (the rationales for which may not be conscious or explicit for different respondents). For the comparison of folk taxonomies across regions or different cultures, it is thus suggested to aim for the construction of folk taxonomic trees following the principles outlined by Berlin (1992; see Foale, 1998; May, 2005), rather than working with descriptors underlying the classification of different groups. This is likely to work well with larger, heterogeneous groups of respondents or by using tools such as Cultural Consensus Analysis (CCA) techniques (e.g., Grant and Miller, 2004). Applying such quantitative indices allows for the quantitative detection of changes in local ecological knowledge and the assessment of the relative influence of different potential drivers of such change, and thus can be a powerful tool for hypothesis-driven empirical investigations of knowledge systems and to support studies of biodiversity and environmental change. However, it is important to underline that this approach does not capture all, or even the most relevant, aspects of indigenous knowledge, and should not be seen as an alternative to in-depth ethnological investigations, but rather complement them.

CRediT authorship contribution statement

Shankar Aswani: Conceptualization, Methodology, Investigation, Resources, Writing - original draft, Writing - review & editing, Supervision, Project administration, Funding acquisition. **Sebastian C.A. Ferse:** Conceptualization, Methodology, Software, Validation, Formal analysis, Data curation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Moritz Stäbler:** Software, Formal analysis, Resources, Writing - review & editing, Visualization. **Carolina Chong-Montenegro:** Formal analysis, Data curation, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolind.2020.106865.

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