ETHNOBIOLOGY LETTERS Research Communications

Exploring the Interfaces between Ethnobiology and Ecotoxicology: A Novel Approach

Graziela Dias Blanco[1]*, Natalia Hanazaki[1], Suelen Maria Beeck Cunha[1], Marta Jussara Cremer[2], and Mari Lucia Campos[3]

[1]Department of Ecology and Zoology, Federal University of Santa Catarina, Florianopolis, Brazil. [2]Department of Biological Sciences, University of the Joinville Region, São Francisco do Sul, Brazil. [3]Department of Soils and Natural Resources, State University of Santa Catarina, Lages, Brazil.
*graziblanco@gmail.com

Abstract In recent years, increases in urbanization and industrialization have led to an increase in contaminated areas, which directly affect traditional, indigenous, and local communities who use natural resources for food and medicine. We present a discussion about the use of food resources from areas contaminated with heavy metals and focus on two case studies in southern Brazil. In the first case study, we interviewed 194 residents about the use of plants as food resources or medicine in areas adjacent to abandoned mines, and thus potentially contaminated with heavy metals. In the second case study, we interviewed 39 fishers about the consumption of fish resources from areas potentially contaminated by industrial activities. We also asked about their perceptions regarding contamination, changes in the landscape, and health problems that could be related to contamination. Although people are aware of contamination, consuming local plants and sea food has not stopped because some of these practices are directly linked to their cultural identity; additionally, there might be a lack of public recognition toward contamination. The combination of ethnoecological and ecotoxicological studies is necessary to assess environmental problems caused by heavy metals, as well as concerns about food security and the health of local communities.

Received January 11, 2019
Accepted January 13, 2020
Published May 20, 2020

OPEN ACCESS
DOI 10.14237/ebl.11.1.2020.1493

Keywords Food security, Heavy metals, Ethnoecology, Ecotoxicology, Local communities

Introduction

Ethnobiology and ethnoecology focus on the knowledge, perceptions, and practices of human communities with the surrounding environment, for example by studying artisanal fishing and local communities. These communities perceive and interact with the environment, and systematically use its resources for food, medicine, rituals, and other purposes (Bordeleau et al. 2016). Food, in particular, is of great cultural, social, and nutritional importance for communities that depend directly on the availability and quality of these resources (Bordeleau et al. 2016). However, over the last several decades, ethnobiological studies around the world have shown increasing changes in local knowledge and practices due to urbanization and industrialization (Aswani and Sabetian 2009). Contemporary urbanization occurs at a different scale than historical patterns of urban growth and drives local and regional environmental changes, such as large-scale landscape changes and the increased production of garbage and residuals (Seto et al. 2010). This dramatic shift has also resulted in changes to the chemical environment and peoples' exposure to pollutants, which affect and contaminate soils and water resources (Grimm et al. 2008). In this regard, we need to deepen our understanding of the effects of changes in the quality of the food resources consumed by local communities.

An increase in contaminants due to urbanization and industrialization affects the quality of species used for food and medicine, which can be contaminated with chemical residues due to polluted water in basins, rivers, and estuaries (FAO 2017) and directly affects quality of life and health. The use of contaminated environments by fisheries, for example, can be related to risks to the health of fishers (Rios et al. 2011). This is due to the periodic and systematic consumption of polluted aquatic resources (e.g., due to industrial waste, sewage, heavy metals, and widespread use of pharmacological substances). These pollutants can cause cumulative and serious health effects such as deep cutaneous lesions (Ribeiro et al. 2015). According to Järup (2003), these risks are likely related to the passive, chronic effects of long-term exposure rather than the sporadic exposure of contaminated food.

According to the U.S. Agency for Toxic Substances and Disease Registry (ATSDR), the most potentially problematic inorganic pollutants for human health are As (arsenic), Hg (mercury), Cd (cadmium), Pb (lead), and Cr (chromium). These elements may be present in water resources, soil, and air, and may be associated with disease prevalence in humans (ATSDR 2018; Hess 2018). For example: the ingestion of food contaminated with As, even at low levels, can be related to diabetes (Grau-Perez et al. 2018); long-term ingestion of Hg can affect the neurological system (Hess 2018; Kim et al. 2016); Cd exposure affects the renal system and increases the probability of gestational diabetes mellitus (Madrigal et al. 2019; Xing et al. 2018); and Pb damages the central nervous system and impairs the functions of lysosomes in neural cells (Gu et al. 2019).

An increase in contaminated areas also harms the quality of food resources (Aswani and Sabetian 2009). Ecotoxicological studies blame this increase in contaminated areas on mining practices, the use of pesticides in agriculture, and the wide use of pharmaceutical products (Elibariki and Maguta 2017; Shia et al. 2018). Although these authors report different environmental effects depending on the contamination, all report one factor in common: the presence of human communities near contaminated areas. In several situations, indigenous peoples and local communities are among the most affected communities (Khlifi et al. 2014). This situation was observed in local communities in China (Guan et al., 2017), northern Europe (Tóth et al. 2016), Canada (Chan and Receveur 2000), and in Latin America, with indigenous peoples and fishers (Luo et al. 2013; Miller and Villarroel 2018; Villegas et al. 2018).

Heavy metals, both in soil and water, are among the most environmentally challenging contaminants due to their capacity for bioaccumulation along the trophic chain—where they accumulate in tissues and change metabolic routes—and their impacts on the environment (Ali et al. 2013; Carolin et al. 2017). The greater the proximity of areas with easily accessible resources, the greater the probability that these areas will be visited and exploited for their resources (Gaoue et al. 2017). However, the overlap of contaminated areas with areas that provide resources is worrying. Pinheiro et al. (2000) noted this concern for the contamination of food resources by heavy metals due to the process of gold mining in Amazonian rivers, which uses Hg as an amalgam to separate gold particles. This is a problem because the Hg is processed by sedimentary bacteria and released as methylmercury, becoming bioavailable in the aquatic environment and accumulating in the food chain. Currently, Hg is a major contaminant of Amazonian rivers, reaching several trophic levels in this ecosystem (Almeida-Rodrigues et al. 2019; Anjos et al. 2016). Consequently, there has been an increase in the exposure to this metal in riverine populations, such as fishers, due to the consumption of contaminated fish (Anjos et al. 2016; Pinheiro et al. 2000).

Silvano and Begossi (2016) explored the trophic levels of targeted fish consumed by artisanal fishers as well as the Hg content of these fish species, and emphasized the importance of linking local knowledge to ecotoxicology research. In a study in Amazonia, Boischio (1996) also showed that traditional knowledge is important to identify foci of contamination for fishery resources consumed by riverine people. This link between local knowledge and ecotoxicology can contribute to improving the management of aquatic ecosystems, revealing the potential for new applications of fishers' knowledge to ecotoxicology, which could improve management of aquatic ecosystems and strengthen fishers' political status (Silvano and Begossi 2016). We add to this potential the paramount importance of focusing on the health of users, since exposure to contaminants can have dramatic long-term implications (Colborn et al. 1993).

We contribute a novel approach to explore the interfaces between ethnobiology and ecotoxicology based on two ongoing studies of similar situations: an area highly contaminated by mining, characterized by the extraction of coal; and an estuarine area with a history of industrial, agricultural, and sedimentation problems. In both regions there are areas traditionally used for the extraction of resources that are affected by contamination from nearby economic activities.

In southern Brazil, several communities have been exposed to heavy metals. The state of Santa Catarina is one of the main coal extractors and has the highest concentration of mining in the country (Klein 2006). Mining occurs very close to residential areas and several settlements and cities have been formed around or over the mines (Sizenando 2011). In abandoned areas in these places, there are medicinal and food plants (Klein 2006). On the northern coast of Santa Catarina, Babitonga Bay is an estuary that serves as a nursery for many marine species, including estuarine residents and dependents, and is an extremely important area for artisanal fishing. In this region, problems such as sedimentation, changes in hydrodynamics, domestic effluents, and agricultural and industrial effluents from metallurgical and textile industries caused the sedimentation of heavy metals and their availability throughout the entire trophic chain (Cremer et al. 2006). The gravity of this situation is evidenced by the high levels of heavy metals found in fishery resources of Babitonga Bay (Tureck et al. 2006).

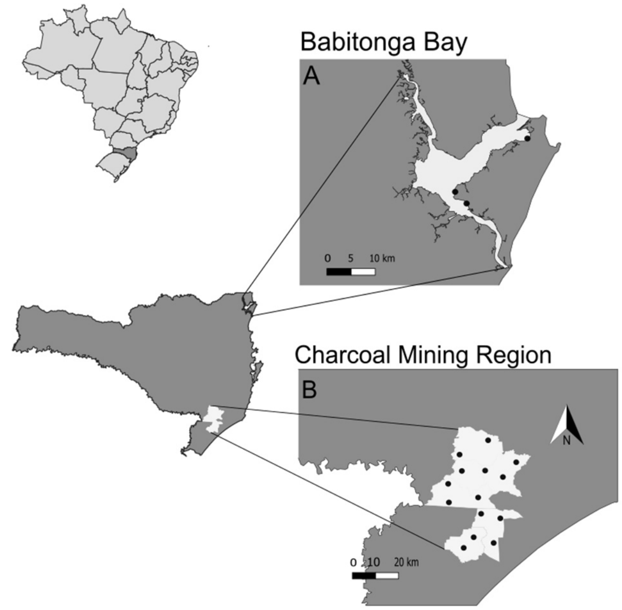

Figure 1 Areas of study in the state of Santa Catarina, Brazil. **A**: Location of the fishing communities that were interviewed in Babitonga Bay. Dots indicate location of fishing communities **B**: Location of local communities that were interviewed in mined areas. Dots indicate the local communities located in the deactivated coal mining areas of the carbonifera region (in gray).

Methods

We focus on two regions of the state of Santa Catarina, in southern Brazil, where there are areas contaminated by heavy metals and a high density of fishers and local communities. The first is the Santa Catarina carboniferous basin, between the municipalities of Ararangua and Lauro Muller, where we conducted interviews in five municipalities (Lauro Muller, Siderópolis, Urussanga, Criciúma, and Treviso) and focused on plant resources used. The second is Babitonga Bay, comprising six municipalities (São Francisco do Sul, Itapoá, Araquari, Joinville, Garuva, and Barra do Sul), where we interviewed artisanal fishers from São Francisco do Sul and focused on fish resources (Figure 1).

We selected at least two local communities from each municipality of the carboniferous region, located within a maximum radius of 300m from the of coal extraction core (e.g., near the contaminated areas). All areas visited have been mined in the past but are no longer in use. In each community, we visited every home and interviewed at least 51% of resident families. At Babitonga Bay, we choose fishing communities located on a gradient of exposure to sources of contamination, from the interior of the bay (near industrial areas) to the bay opening to the sea. We selected respondents by the peer recommendation method (Davis and Wagner 2003) and snowball sampling (Bernard 2006), including fishers who agreed to participate and met the following criteria: fish within Babitonga Bay for at least 10 years; 2) have a link with the territory they live in; and 3) have been consuming marine resources from within Babitonga Bay for at least 10 years.

In the two regions, after prior informed consent, we used semi-structured interviews and guided tours with the interviewees to sites where plants and seafood are collected to understand the main resources consumed and for what purposes (in the case of medicinal plants). Interviews occurred between January and February 2018 in the carboniferous basin and between June and October 2017 at Babitonga Bay. The central question for the carboniferous basin interviews was if the interviewee collected plant species from the mining area, and for what purposes. At Babitonga Bay we interviewed only fishers, and we asked interviewees about which species were fished or collected for direct consumption. We also asked about their perceptions related to contamination (including awareness about mining areas and landscape changes in the case of plants, and awareness about contaminated spots and pollution in the case of fisheries), as well as possible health issues related to this contamination. For all interviews, we also collected socio-economic data (such as gender, age, length of residence). Interviews were done by G. D. Blanco, S. M. B. Cunha, and a team of trained interviewers from the Human Ecology and Ethnobotany Laboratory between December 2017 and February 2018. We conducted 194 interviews in the carboniferous basin, in contiguous areas to abandoned mining sites. In total, 136 women and 57 men were interviewed. At Babitonga Bay we did 39 interviews, with 8 women and 31 men. Plants were identified based on collected and archived botanical specimens (collector numbers G. D. Blanco 90–120) and aquatic animals were identified based on literature (Costa et al. 2011; Lopes 2015; Martins 2011; Medeiros et al. 2010; Villar et al 2011) and showing photographs of the organisms to the interviewees.

Results

Collecting Plants Where Charcoal Was Mined

The predominant age group was between 45 and 65 years old and the average age was 53 years old. Among the interviewees, 22% had always lived in the area. For the others, the average length of on-site living was around 30 years. More than half of the interviewees collect medicinal or food plants in the surrounding areas and more than 90% also plant species in areas around their homes, which can have contaminated soil. Most cited that the species used were *Achyrocline satureioides* (45% of the interviews), *Baccharis* spp. (28%), *Plectranthus barbatus* (25%), *Citrus* spp. (23%), *Mentha arvensis* (23%), and *Psidium guajava* (14%). The main purposes of medical uses were treating digestive, infectious, and parasitic diseases (54% of respondents) orally with an infusion. When asked about knowledge of the number of mining areas that existed near the places where they lived, almost 80% of the respondents said they knew at least one area and reported environmental (observed changes in the landscape) and health (problems related to respiratory diseases) impacts.

Artisanal Fishing and Presence of Heavy Metals

The predominant age group was between 46 and 54 years old and the average age was 51 years old. The species cited as most consumed were *Mugil curema* (28 interviews), *Mugil liza* (28 interviews), *Micropogonias furnieri* (25 interviews), *Litopenaeus schmitti* (24 interviews), *Crassostrea brasiliana* / *C. rhizophorae* (19 interviews), and *Callinectes danae* / *C. sapidus* (19 interviews). Fishers (14 interviews) reported avoiding areas that they thought had general pollution or heavy metal pollution (2 interviews). Respondents referred to resource-related problems and said they avoided cockle (*Anomalocardia brasiliana*) or crab (*Ucides cordatus*) because they consider them to be contaminated with heavy metals or fecal coliforms. In the three communities, interviewed fishers mentioned 18 diseases or health problems, which were categorized according to the World Health Organization (WHO), including high blood pressure, endocrine problems, nutritional and metabolic diseases, and diseases of the eye and adnexa.

Discussion

In both areas, we observed the consumption of resources with risk of contamination by heavy metals. In the carboniferous basin, coal extraction leads to the contamination of surface layers of the soil with pyrite, soil acidification, and increasing concentrations of metals (e.g., aluminum, iron, manganese, copper, nickel, arsenic, lead, cadmium, and zinc) to toxic levels (Campos et al. 2003; Masto et al. 2017). It also contributes contaminants of dust particles and other toxic substances that are released during the extraction process, impairing abiotic and biotic components of the ecosystem, including humans (Masto et al. 2017). The practice of coal extraction contaminates soil and water resources and releases heavy metals which, if consumed, can cause acute and chronic intoxication and impact the functioning of the nervous system. (Masto et al. 2017; Oliveira-Filho et al. 2017). The human communities near these areas are at greater risk and are likely to be contaminated due to ingestion, inhalation, or skin contact (Masto et al. 2017).

This result is alarming, since studies in other countries of South America, as well as in the United States, Europe, India, China, and Korea showed that plant species associated with medicinal or food use have bioaccumulating potential, including *Baccharis crispa*, *Baccharis sarothroides*, *Mentha arvensis*, and *Psidium* *guajava* (Manikandan et al. 2015; Menezes et al. 2013; Oti 2015).

At Babitonga Bay, previous studies have found disturbing levels of contaminants in fishery resources (Cremer et al. 2006; Tureck et al. 2006). Resident populations of the Franciscana dolphin (*Pontoporia blainvillei*), which is at a high trophic level, showed high levels for octocrylene (Gago-Ferrero et al. 2013) and PCBs (Dorneles et al. 2013) in this area. However, links between fishing and consuming seafood with contaminants have not been investigated. Our results show that fishers are at risk of contamination due to the consumption of several species. For example, among the species most consumed are oysters (*Crassostrea brasiliana / C. rhizophorae*), which had a cadmium level of 3.08 ppm (Tureck et al. 2006). This is above the maximum limit (0.05 mg.kg-1) established by the MERCOSUL Technical Regulation (ANVISA 2013) for raw, frozen, or chilled fish, except for bonito, carapeba, eel, mullet, mackerel, sardines, tuna and flatfish (0.10 mg.kg-1), bluerunner and swordfish (0.30 mg.kg-1), cephalopod and bivalve mollusks (2.00 mg.kg-1), and crustaceans (0.50 mg.kg-1).

Historically, contamination of soil and water resources has been treated solely as an environmental problem (Lu et al. 2015), but it is imperative to address the public health and food security of local communities. The increase of contaminated areas in the last decades aggravates this situation, especially with the contamination of resources used by indigenous peoples and local communities (Elibariki and Maguta 2017; Pinheiro et al. 2000). Among the contaminants present in the environment, heavy metals are an environmental and public health challenge (Silva and Ferreira 2015). According to Lu et al. (2015), prolonged exposure to areas contaminated with heavy metals may contribute to a range of diseases related to digestive system problems, miscarriages, and an increased risk of cancer, especially in the digestive tract. This worrying situation is even more serious for local communities who rely on those resources, since the quality of the environment is essential for their cultural identity and is closely linked to the livelihood and the quality of life of these groups (Bordeleau et al. 2016).

This is the reality of artisanal fishing of Babitonga Bay and local communities of the coal belt of Santa Catarina. Although these communities perceive the contamination of the areas, fishing and collecting food resources still occur and these practices are closely linked to the local food culture and subsistence. However, it is possible that the risk of diseases due to contamination by heavy metals has increased, as observed in other regions (Vega et al. 2018), so further studies about this subject are needed.

When analyzing this from the point of view of trophic webs, the presence of persistent contaminants, such as heavy metals, can reach the entire ecosystem. In environments where the soil is contaminated, the plant species are the first to absorb the contaminants and these may be passed on to the people who consume them (Lu et al. 2015). The same can occur in estuaries and mangroves, which are nursery areas for many species (e.g., crustaceans and fish). Nursery areas are also suitable for the accumulation of heavy metals in the sediment, which become bioavailable to living things (Pinheiro et al. 2012) and the people who consume these organisms.

We have argued toward a new perspective, yet we are revisiting Carson's (1962) argument in her seminal Silent Spring: how can we as humanity be allowed to poison ourselves? Bioaccumulation and biomagnification are not new issues in science (e.g., Flinders 2006). More than two decades ago, Colborn et al. (1993) warned of the long-term dangers of a number of environmental contaminants, including to heavy metals. They also showed the problems and difficulties in isolating the causes of environmental contamination that may have multiple sources in a world increasingly dependent on chemical by-products. The multiple causes cannot be used as an argument towards the lack of concrete evidence of contamination. Addressing the ecotoxicology problems of contaminants, such as heavy metals directly related to mining, industrial, and port activities is only the beginning of the task to understand and avoid the health risks of historically marginalized and vulnerable populations often featured in ethnobiology studies.

The risk of heavy metal contamination in the food of local communities is a reality. For this reason, as a new approach to this issue, we suggest a threefold strategy of investigation. First, researchers must identify potential sources of contamination (such as mining and industrial activity in our case) and collect local ecological knowledge about resource use, resource contamination, and environmental contamination. Second, researchers should collect samples of potentially contaminated resources, which may be based on local knowledge, and analyze them for the degree of contamination. Third, researchers should correlate local perceptions about health problems with cross-sectional health data, if available, to investigate the prevalence of diseases and symptoms that can be related to environmental contamination.

The presence of such as fishermen and indigenous people and local communities in contaminated areas should be treated as a matter of food security and public health. The increase in contaminated areas that overlap with vulnerable populations is a reality and must be treated efficiently and with different approaches. For example, Duarte et al. (2016) combined ecotoxicological studies of Ucides cordatus and measures of population density, showing how multi-level biological responses can reflect the conservation status of mangrove areas with different degrees of human impacts. Combining different approaches can help explain the effects of pollution on human health. Ethnoecological and ethnobiological studies help in this debate by highlighting the resources consumed and the places where they are obtained, as well as perceptions about symptoms and diseases that may be related to contamination.

Acknowledgements
We are grateful to P. F. Corrêa, E. Rocha, H. Souza, M. Cabral and F. Moraes for support in data collection, and to C. Soares for comments in a previous version of this text.

Declarations
Permissions: In order to carry out the present research, the necessary authorizations were obtained with CEPSH (Ethics Commitee on Research with Human Beings of Universidade Federal de Santa Catarina, processes number 71339817.7.0000.0121 and 0660217.1.0000.0121). All interviewees signed a free informed consent term.
Sources of funding: This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brasil (CAPES)—Finance Code 001. NH and MJC thanks to CNPq for their research productivity scholarships (309613/2015-9 and 10477/2017-4).

Conflicts of Interest: None declared.

References Cited
Ali, H. E. K., and M. A. Sajad. 2013. Phytoremediation of Heavy Metals—Concepts and Applications. *Chemosphere* 91:869–881. DOI:10.1016/j.chemosphere.2013.01.075.

Almeida-Rodrigues, P., R. G. Ferrari, L. N. dos Santos, and C. A. C. Junior. 2019. Mercury in Aquatic Fauna Contamination: A Systematic Review on its Dynamics and Potential Health Risks. *Journal of Environmental Sciences* 101:1–14. DOI:10.1016/j.jes.2019.02.018.

Anjos, M. R., N. G. Machado, M. E. P. Da Silva, W. R. Bastos, M. R. Miranda, D. P. Carvalho, M. H. Mussy, I. B. B. Holanda, M. S. Biudes, and J. A. Fulan. 2016. Bioaccumulation of Methylmercury in Fish Tissue from the Roosevelt River, Southwestern Amazon. *Revista Ambiental e Água* 11:508–518. DOI:10.4136/ambio-agua.1830.

ANVISA. 2013. Resolução- RDC Nº 42, de 29 de agosto de 2013—Limites Máximos de Contaminantes Inorgânicos em Alimentos. Available at: http://portal.anvisa.gov.br/documents/33880/2568070/rdc0042_29_08_2013.pdf/c5a17d2d-a415-4330-90db-66b3f35d9fbd. Accessed on May 2, 2019.

Aswani, S., and A. Sabetian. 2009. Implications of Urbanization for Artisanal Parrotfish Fisheries in the Western Solomon Islands. *Conservation Biology* 24:520–530. DOI:10.1111/j.1523-1739.2009.01377.

ATSDR. 2018. Agency for Toxic Substances and Disease Registry. Available at: https://www.atsdr.cdc.gov/index.html. Accessed on May 2, 2019.

Bastos, G . C. 2006. Atividade Pesqueira na Baía da Babitonga. In *Diagnóstico Ambiental da Baía da Babitonga*, edited by M. J. Cremer, P. R. D. Morales, and T. M. N. Oliveira. Univile, Brasil.

Bernard, H. R. 2006. *Methods in Research Anthropology*, 4th edition. AltaMira Press, New York, NY.

Boischio, A. A. P. 1996. Human Ecology of Riverside People (Caboclos or Ribeirinhos) along the Upper Madeira River with Focus on Mercury Pollution through Fish Consumption. Doctoral Dissertation, School of Public and Environmental Affairs, Indiana University, Bloomington, IN.

Bordeleau, S., H. Asselin, M. J. Mazerolle, and L. Imbeau. 2016. "Is it Still Safe to Eat Traditional

Food?" Addressing Traditional Food Safety Concerns in Aboriginal Communities. *Science of the Total Environment* 565:529–538. DOI:10.1016/j.scitotenv.2016.04.189.

Campos, M. L., J. A. Almeida, and L. S. Souza. 2003. Avaliação de Três Áreas de Solo Construído após Mineração de Carvão a Céu Aberto em Lauro Müller, Santa Catarina. *Revista Brasileira de Ciência do Solo* 27:1123–1137. DOI:10.1590/S0100-06832003000600017.

Carolin, C. F., P. S. Kumar, A. Saravanan, G. J. Joshiba, and M. Naushad. 2017. Efficient Techniques for the Removal of Toxic Heavy Metals from Aquatic Environment: A Review. *Journal of Environmental Chemical Engineering* 5:2782–2799. DOI:10.1016/j.jece.2017.05.029.

Carson, R. 1962. *Silent Spring*. Riverside Press, Cambridge, MA.

Chan, H. M., and O. Receveur. 2000. Mercury in the Traditional Diet of Indigenous Peoples in Canada. *Environmental Pollution* 110:1–2. DOI:10.1016/S0269-7491(00)00061-0.

Colborn, T., F. S. Vom Saal, and A. M. Soto. 1993. Developmental Effects of Endocrine-Disrupting Chemicals in Wildlife and Humans. *Environmental Health Perspectives* 101:378–384. DOI:10.1289/ehp.93101378.

Costa, M. D. P., P. R. Schwingel, and H. L. Spach. 2011. Assessment of Larval Distribution of Invasive *Omobranchus punctatus* (Valenciennes, 1836) (Pisces: Blenniidae) in a Subtropical Estuary (Southern Brazil). *Aquatic Invasions Records* 6:33–38.

Cremer, M. J., P. R. D. Morales, and T. M. N de Oliveira. 2006. *Diagnóstico Ambiental da Baía da Babitonga*. Univile, Brasil.

Davis, A., J. R. Wagner. 2003. Who Knows? On the Importance of Identifying "Experts" When Researching Local Ecological Knowledge. *Human Ecology* 31:463–489. DOI:10.1023/A:1025075923297.

Dorneles, P. R., P. S. G. Eppe, A. F. Azevedo, C. P. Bertozzi, M. A. Martínez, E. R. Secchi, L. A. Barbosa, M. Cremer, M. A. Alonso, J. P. M Torres, J. Lailson-brito, O. Malm, E. Eljarrat, and B. D. Krishna. 2013. High Accumulation of PCDD, PCDF, and PCB Congeners in Marine Mammals from Brazil: A Serious PCB Problem. *Science of the Total Environment* 463:309–318. DOI:10.1016/j.scitotenv.2013.06.015.

Duarte, L. F. A., C. A. Souza, C. R. Nobre, C. D. Pereira, and M. A. A. Pinheiro. 2016. Multi-Level Biological Responses in *Ucides cordatus* (Linnaeus, 1763) (Brachyura, Ucididae), as Indicators of Conservation Status in Mangrove Areas from the Western Atlantic. *Ecotoxicology and Environmental Safety* 133:176–187. DOI:10.1016/j.ecoenv.2016.07.018.

Elibariki R., and M. M. Maguta. 2017. Status of Pesticides Pollution in Tanzania—A Review. *Chemosphere* 178:154–164. DOI:10.1016/j.talanta.2003.11.047.

FAO, 2017. Climate Change and Food Security and Nutrition Latin America and the Caribbean. Available at: http://www.fao.org/3/a-i6311e.pdf. Accessed on May 02, 2019.

Flinders, C. 2006. The Potential for Bioaccumulation, Bioconcentration, and Biomagnification of Selected Metals in an Aquatic Food Chain: A Literature Review. *Technical Bulletin* 927:1–48.

Gago-Ferrero, P., M. Alonso, C. P. Bertozzi, J. Marigo, L. A. Barbosa, M. J. Cremer, E. R. Secchi, A. F. Azevedo, J. Lailson-Brito, J. P. Torres, O. Malm, E. Eljarrat, M. S. Diaz-Cruz, and D. Barcelo. 2013. First Determination of UV Filters in Marine Mammals. Octocrylene Levels in Dolphins. *Environmental Science & Technology* 4:5619–5625. DOI:10.1021/es400675y.

Gaoue, O. G., M. A. Coe, M. Bond, G. Hart, B. C. Seyler, and H. McMillen. 2017. Theories and Major Hypotheses in Ethnobotany. *Economic Botany* 71:269-287. DOI:10.1007/s12231-017-9389-8.

Grau-Perez M., A. A. Navas-Acien, I. Galan-Chilet, C. M. Crainiceanu, G. Marco, P. R. Garrido, Garcia-Barrera, J. L. Gomez-Ariza, A. Casasnovas, J. C. Martin-Escudero, J. Redon, F. Chaves, and M. Tellez-Plaza. 2018. Arsenic Exposure, Diabetes-Related Genes and Diabetes Prevalence in a General Population from Spain. *Environmental Pollution* 235:948–955. DOI:10.1016/j.envpol.2018.01.008.

Grimm N. B., S. H. Faeth, N. E. Golubiewski, C. L. Redman, J. Wu, X. Bai, and J. M. Briggs. 2008. Global Change and the Ecology of Cities. *Science* 319:756–760. DOI:10.1126/science.1150195.

Gu, X., M. Han, Y. Du, Y. Wu, Y. Xu, X. Zhou, D. Yan, and H. L. Wang. 2019. Pb Disrupts Autophagic Flux through Inhibiting the Formation and Activity of Lysosomes in Neural Cells. *Toxicology in Vitro* 55:43–50. DOI:10.1016/j.tiv.2018.11.010.

Guan, Y., C. Chu, C. Shao, M. Ju, and E. Dai. 2017. Study of Integrated Risk Regionalisation Method for Soil Contamination in Industrial and Mining Area. *Ecological Indicators* 83:260–270. DOI:10.1016/j.ecolind.2017.08.003.

Hess, S. C., ed. 2018. *Ensaios Sobre Poluição e Doenças no Brasil.* Outras Expressões, Brasil.

Järup, L. 2003. Hazards of Heavy Metal Contamination. *British Medical Bulletin* 68:167–182. DOI:10.1093/bmb/ldg032.

Khlifi, R., P. Olmedo, F. Gil, M. Feki-Tounsi, B. Hammami, A. Rebai, and A. Hamza-Chaffai. 2014. Biomonitoring of Cadmium, Chromium, Nickel, and Arsenic in General Population Living near Mining and Active Industrial Areas in Southern Tunisia. *Environmental Monitoring and Assessment* 186:761–779. DOI:10.1007/s10661-013-3415-9.

Kim, K. H., E. Kabir, and S. A. Jahan. 2016. A Review on the Distribution of Hg in the Environment and its Human Health Impacts. *Journal of Hazardous Materials* 306:376–385. DOI:10.1016/j.jhazmat.2015.11.031.

Klein A. S. 2006. Áreas Degradadas pela Mineração de Carvão no Sul de Santa Catarina: Vegetação Versus Substrato. Masters Thesis, Department of Environmental Sciences, Universidade do Extremo Sul Catarinense, Lages, SC.

Lopes, P. R. 2015. Ecologia Alimentar e Especial da Toninha (*Pontoporia blainvillei*) e do Boto-Cinza (*Sotalia guyanensis*) na Baía da Babitonga, Sul do Brasil. Masters Thesis, Universidade Federal de Santa Catatrina, Florianopolis, Santa Catarina.

Lu, Y., S. Song, R. Wang, Z. Liu, J. Meng, A. J. Sweetman, A. Jenkins, R. C. Ferrier, H. Li, W. Luo, and T. Wang. 2015. Impacts of Sand Water Pollution on Food Safety and Health Risks in China. *Environment International* 77:5–15.

Luo, A., Gao, L., Yang, X., Peng, H., Xing, Y. 2013. A Compound Containing Substituted Indole Ligand from a Hyperaccumulator Sedum Alfredii Hance Under Zn Exposure. *International Journal of Phytoremediation* 15:952–964. DOI:10.1080/15226514.2012.751351.

Madrigal, J. M., A. C. Ricardo, V. Persky, and M. Turyk. 2019. Associations between Blood Cadmium Concentration and Kidney Function in the US Population: Impact of Sex, Diabetes and Hypertension. *Environmental Research* 169:180–188. DOI:10.1016/j.envres.2018.11.009.

Martins, T. S. 2011. Caracterização Hidrodinânimca e Teste do Modelo de Transporte Lagrageano para Avaliar a Retenção de Ovos e Larvas de Peixes na Baia Babitonga, SC. Completion of Coursework, Department of Biology, Universidade do Vale do Itajaí, Itajaí, Santa Catarina.

Manikandan, R., S. V. Sahi, and P. Venkatachalam. 2015. Impact Assessment of Mercury Accumulation and Biochemical and Molecular Response of *Mentha arvensis*: A Potential Hyperaccumulator Plant. *The Scientific World Journal* 15:17–27. DOI:10.1155/2015/715217.

Masto, R. E., G. Joshy, T. K. Rout, and L. C. Ram. 2017. Multi-Element Exposure Risk from Soil and Dust in a Coal Industrial Area. *Journal of Geochemical Exploration* 176:100–107. DOI:10.1016/j.gexplo.2015.12.009.

Medeiros, P. M., A. L. S. Almeida, R. F. P. Lucena, F. J. B. Souto, U. P. Albuquerque. 2010. Uso de Estímulos Visuais na Pesquisa Etnobiológica. In: *Métodos e Técnicas na Pesquisa Etnobiológica e Etnoecológica*, edited by U. P. Albuquerque, R. F. P. de Luceana, and L. V. F. C. Cunha, pp. 151–170. Nupeea, Brasil.

Menezes, A. P. S., J. Da Silva, J. R. Reyes, R. Debastiani, J. F. Dias, P. Rohr, and A. B. F. Ferraz. 2013. *Baccharis crispa* (Less.) DC as Genotoxicity Indicator of Exposure to Coal and Emissions from a Thermal Power Plant. *Archives of Environmental Contamination and Toxicology* 65:434–441. DOI:10.1007/s00244-013-9918-0.

Miller, J. R., and L. F. Villarroel. 2019. Bolivia: Mining, River Contamination, and Human Health. *Encyclopedia of Environmental Health* 436–455. DOI:10.1016/B978-0-12-409548-9.10943-1.

Oliveira-Filho, L. C., D. Baretta, T. Zortéa, J. P. M. Oliveira, and J. C. P. Santos. 2017. Resíduo Piritoso Provoca Toxicidade Aguda e Crônica em Collembola e Oligochaeta. *Revista Scientia Agraria* 18:64–75. DOI:10.5380/rsa.v17i3.50209.

Oti, W. O. 2015. Bioaccumulation Factors and Pollution Indices of Heavy Metals in Selected Fruits and Vegetables From a Derelict Mine and Their Associated Health Implications. *International Journal of Environment and Sustainability* 4:15–23.

Pinheiro, M. C. N., J. Nakanishi, T. Oikawa, G. Guimarães, M. Quaresma, B. Cardoso, W. W. Amoras, M. Harada, C. Magno, J. L. F. Vieira, M. B. Xavier, and D. R. Bacelar. 2000. Methylmercury Human Exposure in Riverine Villages of Tapajos Basin, Pará State, Brazil. *Revista da Sociedade Brasileira de Medicina* 33:265–269. DOI:10.1590/S0037-86822000000300005.

Pinheiro, M. A. A., P. P. Gandara, L. F. A. D. Silva, A. A. Almeida, and F. P. Zanotto. 2012. Accumulation of Six Metals in the Mangrove Crab *Ucides cordatus* (Crustacea: Ucididae) and its Food Source, the Red Mangrove *Rhizophora mangle* (Angiosperma: Rhizophoraceae). *Ecotoxicology and Environmental Safety* 81:114–121. DOI:10.1016/j.ecoenv.2012.05.004.

Ribeiro, C. R. B., V. M. Sabóia, D. K. Souza, and A. P. A. Moreira. 2015. A Saúde de Pescadores Artesanais e Ocorrência de Feridas Cutâneas: Novos Rumos para a Enfermagem. *Revista de Pesquisa de Cuidados Fundamentais* 7:1946–1953. DOI:10.9789/2175-5361.2015.

Rios, A. O., R. D. C. F. Rego, and P. G. L. Pena. 2011. Doenças em Trabalhadores da Pesca. *Revista Baiana de Saúde Pública* 35:175–188.

Seto, K. C., R. Sánchez-Rodríguez, and M. Fragkias. 2010. The New Geography of Contemporary Urbanization and the Environment. *Annual Review of Environment and Resources* 35:167–194. DOI:10.1146/annurev-environ-100809-125336.

Shia, T., J. Mab, X. Wub, T. Jub, X. Linb, Y. Zhangb, X. Lib, Y. Gongb, H. Houb, L. Zhaob, and F. Wua. 2018. Inventories of Heavy Metal Inputs and Outputs to and from Agricultural Soils: A Review. *Ecotoxicology and Environmental Safety* 164:118–124. DOI:10.1016/j.ecoenv.2018.08.016.

Silva, L. M., and R. L. Ferreira. 2015. Impacto Ambiental pela Mineração de Carvão no Sul de Santa Catarina. *Caderno Meio Ambiente e Sustentabilidade* 6:54–71.

Silvano, R. M., and A. Begossi. 2016. From Ethnobiology to Ecotoxicology: Fishers' Knowledge on Trophic Levels as Indicator of Bioaccumulation in Tropical Marine and Freshwater Fishes. *Ecosystems* 19:1310–1324. DOI:10.1007/s10021-016-0002-2.

Sizenando, J. W. 2011. Mineração e Espacialidade Socioambiental: Exploração Carbonífera e Ocupação Territorial em Criciúma. Masters Dissertation, Department of Soil, Universidade do Extremo Sul Catarinense, Lages, SC.

Tóth, G., T. Hermann, M. R. Da Silva, and L. Montanarella. 2016. Heavy Metals in Agricultural Soils of the European Union with Implications for Food Safety. *Environment International* 88:299–309. DOI:10.1016/j.envint.2015.12.017.

Tureck, R. F., T. M. N. Oliveira, M. J. Cremer, and J. C. Bassfeld. 2006. Avaliação de Metais Pesados em Tecidos de Ostras *Crassostrea gigas*, Cultivada na Baía da Babitonga, Litoral Norte de Santa Catarina. *Revista de Ecotoxicologia e Meio Ambiente* 16:53–62.

Vega, C. M., D. Y. J. I. D. Orellana, M. W. Oliveira, S. S. Hacon, and P. C. Basta. 2018. Human Mercury Exposure in Yanomami Indigenous Villages from the Brazilian Amazon. *International Journal of Environmental Research and Public Health* 15:1051–1064.

Vilar, C., H. L. Spach, and J. M. Souza-Conceiçao, 2011. Fish Assemblage in Shallow Areas of Baía da Babitonga, Southern Brazil: Structure, Spatial, and Temporal Patterns. *Pan-American Journal of Aquatic Sciences* 6:303–319.

Villegas, V., N. Paucar, N. Clavijo, F. Ther, E. Parraguez-Vergara, and B. Contreras. 2018. Does Indigenous and Campesino Traditional Agriculture Have Anything to Contribute to Food Sovereignty in Latin America? Evidence from Chile, Peru, Ecuador, Colombia, Guatemala and Mexico. *International Journal of Agricultural Sustainability* 16:326–341. DOI:10.1080/14735903.2018.1489361

Xing, Y., W. Xia, B. Zhang, A. Zhou, Z. Huang, Z. Zhang, and S. Xu. 2018. Relation between Cadmium Exposure and Gestational Diabetes Mellitus. *Environment International* 113:300–305