Revista de Gestão Costeira Integrada / Journal of Integrated Coastal Zone Management, 14(4):569-579 (2014)

GESTÃO COSTEIRA INTEGRADA
Journal of Integrated Coastal Zone Management

http://www.aprh.pt/rgci/pdf/rgci-507_Eastman.pdf | DOI: 10.5894/rgci507

The potential for young citizen scientist projects: a case study of Chilean schoolchildren collecting data on marine litter*

Lucas Eastman[a]; Valeria Hidalgo-Ruz[a], Vivian Macaya-Caquilpán[a], Paloma Nuñez[a], Martin Thiel[@, a, b, c]

ABSTRACT

A wealth of environmental and ecological questions are answered with the help of citizen scientists of all ages, but schoolchildren (<18 years) rarely participate in these projects. This is surprising considering that many citizen science projects would ideally complement modern school curricula, ranging from science, to math, reading and arts. Here we present a citizen science project supported by schoolchildren who investigate the problem of marine litter along the Chilean coast. Schoolchildren received specially designed education materials, carefully tested instructions and sampling kits. Wherever possible they were accompanied by recent university graduates, who supported the teacher in supervising the sampling process. After the samplings, schoolchildren were enthusiastic and expressed interest in participating in future environmental projects. Based on our experience, we present seven steps for designing a successful citizen science project with schoolchildren. We suggest that involving schoolchildren in citizen science projects will not only enhance the spatial and temporal scale of data collection, but also support school curricula, public understanding of the scientific process, and environmental management decisions.

Keywords: citizen science, schoolchildren, data collection, education materials, marine litter

RESUMO

O potencial para projetos de jovens cientistas cidadãos: um estudo de caso de alunos chilenos na recolha de dados sobre lixo marinho

Uma grande variedade de questões ambientais e ecológicas são respondidas com a ajuda de cidadão cientistas de todas as idades, mas os alunos (<18 anos) raramente participam nestes projetos. Isto é surpreendente, considerando que muitos projetos científicos de cidadania idealmente complementam os modernos currículos escolares, que vão desde ciência, matemática, leitura e artes. Aqui apresentamos um projeto de ciência e cidadania apoiada por alunos que investigam o problema do lixo marinho ao longo da costa chilena. Os alunos receberam materiais de educação especialmente concebidos, instruções cuidadosamente testadas e kits de amostragem. Sempre que possível, os alunos foram acompanhados por jovens diplomados, que apoiaram o professor na supervisão do processo de amostragem. Após as recolhas, os alunos estavam entusiasmados e manifestaram interesse em participar em futuros projetos ambientais. Com base na nossa experiência, apresentamos sete passos para a conceção de um projeto de ciência e cidadania bem sucedido com alunos. Sugerimos que envolver alunos em projetos de ciência e cidadania irá não só aumentar a escala espacial e temporal da recolha de dados, mas também apoiar currículos escolares, a compreensão pública do processo científico, e as decisões de gestão ambiental.

Palavras-chave: *Ciência cidadã; alunos; recolha de dados; materiais de educação; lixo marinho*

[@] Corresponding author to whom correspondence should be addressed: Thiel <thiel@ucn.cl>

[a] Universidad Católica del Norte, Facultad Ciencias del Mar, Larrondo 1281, Coquimbo, Chile

[b] Millennium Nucleus Ecology and Sustainable Management of Oceanic Island (ESMOI), Coquimbo, Chile

[c] Centro de Estudios Avanzados en Zonas Áridas, CEAZA, Coquimbo, Chile

* *Submission: 21 APR 2014; Peer review: 20 MAY 2014; Revised: 9 JUL 2014; Accepted: 26 JUL 2014; Available on-line: 16 SEP 2014*

1. Introduction

The study of many environmental and ecological questions requires the collection of data over dense spatial and temporal scales (Devictor *et al.*, 2010; Hochachka *et al.*, 2012). Where these data cannot be obtained remotely (e.g. by automatic stations or satellites), extensive networks of sampling stations on the ground are needed. Taking frequent samples at many different sites poses enormous challenges for small research teams. Therefore, when data collection can be done by untrained collaborators, scientists often work together with interested citizens, who can come from a wide range of educational backgrounds (Silvertown, 2009). Citizen scientists support a wealth of scientific studies, gathering biological records (from plants to insects, snails, fish and birds), assessing ecological risks (invasive species), and measuring water quality, soil parameters, noise pollution or climate data (*e.g.,* Beaubien & Hamman, 2011; Kolok *et al.*, 2011; Worthington *et al.*, 2011; Bonney *et al.*, 2014).

In the marine management field, challenges like counting whale sightings require vigilance over long periods of time (Davies *et al.*, 2012): an ideal task for a rotating group of young students for a science project. Also, when trying to accurately identify the range of invasive marine species, volunteers can successfully cover the extensive spatial scales needed (Thiel *et al.*, 2014). Instead of using limited university resources to send laboratory members into the field for weeks at a time, trained teachers and their schoolchildren could cover many times more territory due to sheer numbers. National studies that would otherwise be impractical suddenly become possible when one considers using networks of citizen scientists from localities spread along extensive coastlines (Eastman *et al.*, 2013; Hidalgo-Ruz & Thiel, 2013).

Most of these citizen science projects involve adult collaborators, including university students (Dickinson *et al.*, 2010, and references therein). Younger citizens, e.g. schoolchildren, rarely participate in the collection of scientific data (for exceptions see Osborn *et al.*, 2005; Delaney *et al.*, 2008; Braschler *et al.*, 2010; Weckel *et al.*, 2010; Galloway *et al.*, 2006, 2011). This is surprising since many of the aims of citizen science projects nicely complement the objectives of modern school curricula (e.g. Villegas *et al.*, 2010). For example, distinguishing the color morphs in snails and using those data to calculate percentages is something that schoolchildren all over the world can do to support the learning objectives of math classes. Measuring the pH of water samples fits perfectly in the chemistry curriculum. Reading and interpreting instructions complements the objectives of language curricula. The annual schedule of most courses is ideally suited for long-term monitoring programs that require an annual sampling frequency. Engaging schools throughout the state or country would guarantee a high spatial resolution of sampling. Most importantly, though, schoolchildren would gather their data under the supervision of a university-trained teacher (e.g. Galloway *et al.*, 2011), who is knowledgeable in his or her field and also the ideal connection to the research scientists. All these considerations underline the enormous potential for schoolchildren as contributors to citizen science projects.

Our objectives in this contribution are (i) to present the design and some results of a citizen science program, initiated in 2007, in which schoolchildren supported several scientific studies that examined the problem of marine litter along the coasts of Chile, (ii) to provide a guide, based on our experience, of the seven main steps required for successful research projects supported by schoolchildren, (iii) to promote this approach in linking scientists and schoolchildren in the quest to find answers to urgent environmental questions, and (iv) to demonstrate the relevance of data produced by young citizen science studies in coastal management.

A case study: marine litter – a worldwide problem that requires local knowledge

Throughout the world large quantities of anthropogenic litter reach the oceans, causing significant ecological impacts (Gregory, 2009). Litter comes from ships, rivers and shoreline users (Pruter, 1987). Most anthropogenic litter in the sea are plastics (Thompson *et al.*, 2009), which persist for many years in the environment and are distributed throughout all ocean environments (Barnes *et al.*, 2009). Some litter may immediately sink to the seafloor and litter has been found at all depths of the oceans (Barnes *et al.*, 2009). A large proportion of plastic litter floats at the sea surface, smothering coastal environments (Williams & Simmons, 1997), or accumulating in the center of the oceanic gyres (Maximenko *et al.*, 2012). Over time, most of these plastics fragment into ever smaller pieces (Moore, 2008). Plastics of all sizes cause harm to wildlife, fish and marine invertebrates by entanglement or by ingestion (Gregory, 2009; Teuten *et al.*, 2009).

The accumulation of marine litter, and specifically of plastic debris, has caused concern in many countries throughout the world. Most research on the distribution, sources and impacts of marine litter have been conducted in the northern hemisphere. While the problem is widespread in other parts of the world, e.g. in Asia, Africa or South America, knowledge about the distribution and sources of marine litter is limited (Ivar do Sul & Costa, 2007). In particular, in the SE Pacific little information was available about the amounts of marine litter in coastal environments. A quantitative survey in coastal waters had suggested that floating litter was more abundant near coastal cities (Thiel *et al.*, 2003), but the lack of information about litter distribution hinders identification of sources. During a scientific outreach project (http://www.cientificosdelabasura.cl/), schoolchildren recorded large amounts of litter on beaches in northern-central Chile (30° S) and initial observations indicated that most of this litter had local sources because litter had spent little time at sea due to onshore winds and coastal currents (Bravo *et al*., 2009; Thiel *et al*., 2011). Since the coasts of Chile extend over most of the SE Pacific, a program was established to examine the problem of marine litter across 4000 km of shoreline (from 18° S to 53° S). Over the past 7 years this research program was supported by more than 5,000 schoolchildren from all over Chile.

Schoolchildren investigating marine litter in Chile

Scientists in Chile have a long tradition of collaborating with schoolchildren. During the late 1960s the "*Juventudes Científicas de Chile*" (Scientific Youth of Chile) were founded, replicating similar initiatives in Europe. Since the early 1970s the *Juventudes Científicas* were active throughout the country with many local chapters that were directed by university-trained scientists. They conducted summer camps (*Campamento Científico*) and also science fairs for young explorers (*Feria Científica Juvenil*) at the National Museum of Natural History. Supported by individual efforts and despite political turmoil, the *Juventudes Científicas* continued these activities during the 1970s and 80s. Finally, in 1995 the Chilean Science Foundation CONICYT established a program (EXPLORA) that encouraged scientists to return to the classroom and work with schoolchildren. In most cases, scientists let the schoolchildren participate in particular aspects of their current research. Some of these initiatives have gone on to collaborations with school-children to gather new data that otherwise would not be available.

Marine litter is a ubiquitous problem along the entire coast of Chile, but it had remained mostly ignored by the small marine science community, which was mainly occupied with other urgent problems such as shoreline construction, pollution from industry and mining, overfishing, species invasions and others (for overview see Fernández *et al.*, 2000). Given its ubiquity and the fact that counting marine litter does not necessarily require sophisticated equipment, this was considered an ideal topic to be investigated by schoolchildren.

2. Research program and collaborative approach

This program is being conducted along the entire Chilean coast, from Arica in the north (18° S) to Punta Arenas in the south (53° S). Every year a specific research topic is tackled by participating schools, ranging from 30 to 48 schools. Within the program of the *Científicos de la Basura* so far three national research studies have been conducted, on (i) the amounts and types of marine litter, (ii) the quantities and types of microplastics, and (iii) the perceptions of beach users. In the first study schoolchildren counted and classified anthropogenic litter in 9 m^2 plots that were replicated in several transects across the beach. In the second study, they carefully scraped and sieved the upper sand layer from 0.25 m^2 plots; they then sorted and counted all microplastic items retained in the sieve. The perceptions of beach users were obtained from a national survey where schoolchildren interviewed people in their local community, asking them about sources of litter, their littering behaviors and suggestions to mitigate the problem of marine litter.

Each study consists of at least one preparatory activity, the field sampling, and in the most recent study, also a concluding activity. Participating students come from grades 5 to 11. Contacts with the schools were established by phone, email or through local advisors. These scientific advisors, in most cases marine biologists graduated from Universidad Católica del Norte (UCN) who work in administrative positions (*e.g.,* fisheries services or environmental agencies) or at universities across the country, were contacted to support the schoolchildren during the sampling process. Schools were selected to cover the entire country. Most schools readily agreed to participate in the samplings, and for each school one teacher together with his/her course participated in the annual study. These teachers were accompanied by the scientific advisors and were in constant contact with our administrative office via email and telephone. During each study, some schools (< 20 %), which had originally agreed to participate and received all the materials, either did not conduct the sampling or did not send the data or samples. On the other hand, some teachers participated in several studies during successive years.

Learning about the problem and preparation

The participating courses received education materials, instructions and sampling kits. For each activity the research team and artists prepared story books (26 to 34 pages) that were specifically designed for the respective study and targeted to the age group of the participating schoolchildren but were not directly tied to any curriculum. Each story followed a thread that touched on all the environmental issues at stake. For example, the most recent story follows the journey of a little female fish (Jurella) and her friends into the open ocean where they ingest microplastics and become sick (figure 1A and 1B, download the story at http://www. Cientificos-delabasura.cl/docs/jurella.pdf)

The story is fictional, but it contains some factual issues, e.g. that the jurel (horse mackerel – *Trachurus murphyi*) is the most important pelagic fish in Chile, and that larvae and early juvenile stages develop within the Humboldt Current System but then migrate towards open ocean waters (Thiel *et al.,* 2007). Microplastic ingestion by pelagic fishes has indeed been observed (Boerger et al., 2010; Davison & Asch, 2011), but whether *T. murphyi* ingests microplastic is not known at present. Thus, the story itself mingles factual and fictional elements. However, on each page there is a brief paragraph that reports biological and environ-mental facts that are based on the scientific literature (figure 1B).

Each schoolchild receives a personal copy of the story book. During the preparatory class, the schoolchildren read the story in class (figure 1C). Teachers may then discuss particular aspects of the story with their class. The schoolchildren take their copy home where they can continue to read the story and also might share it with family and friends. Adequate educational materials are important assets for citizen science projects (Bonney *et al.,* 2009).

The protocols for the marine litter studies are prepared for the age groups participating in the program (grades 5 – 11). They are initiated by a brief motivational dialogue of fictional characters. These dialogues and the protocols are read during the preparatory class (figure 1D). The sampling protocols are kept as simple as possible, being supported by schematic drawings, data tables and a list of sampling tools (for importance of supporting materials see also Hochachka *et al.,* 2012).

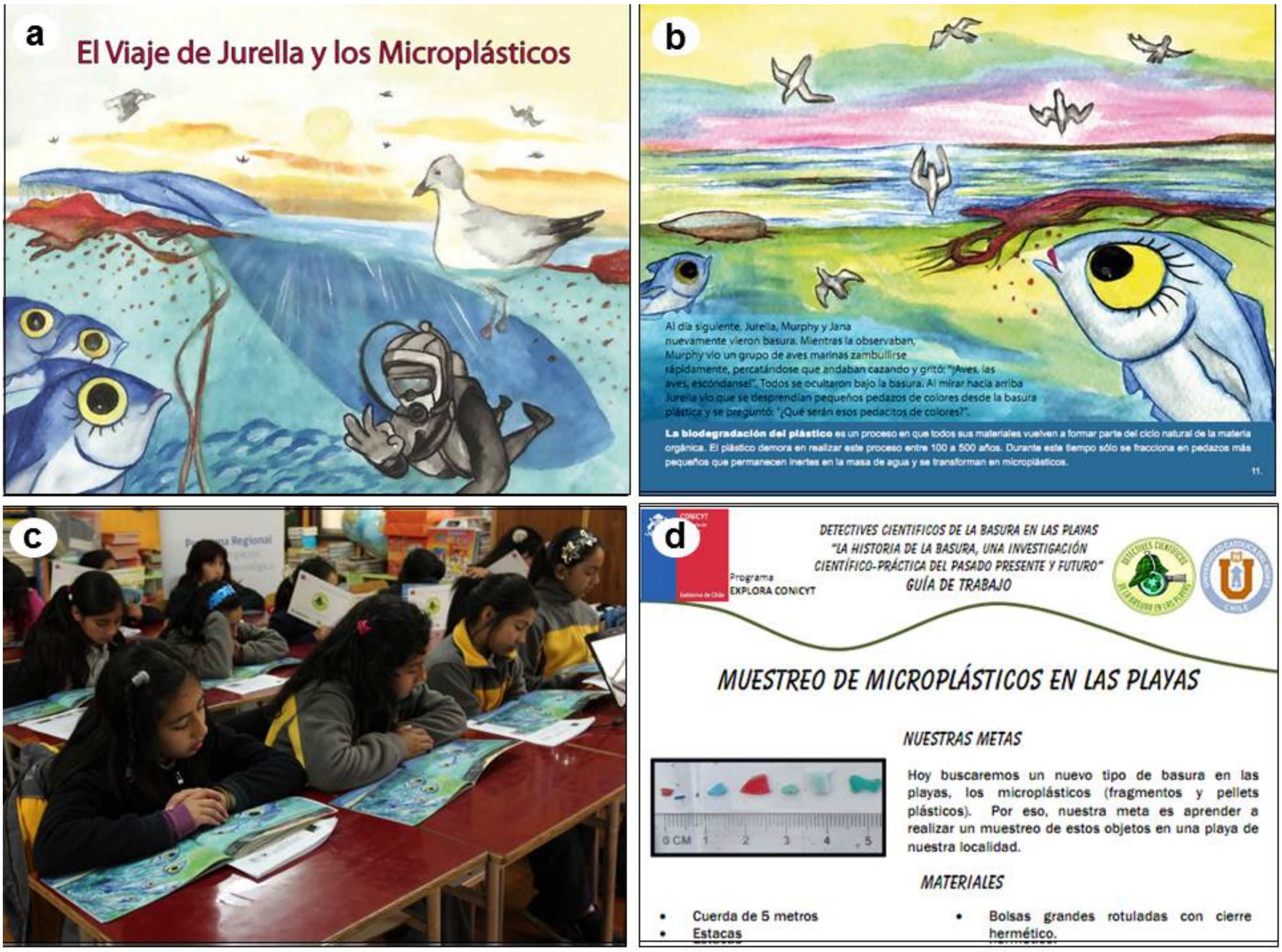

Figure 1 - (A) Cover of the story book reporting the travels of the main character (the young female fish Jurella) together with her friends into the open South Pacific ocean. Translated title: The Travels of Jurella and the Microplastics. (B) Example page from the book with the fictional story in the center and brief facts on the bottom. (C) Schoolchildren reading the story in class. (D) Manual for microplastics sampling. All stories created by the *Cientificos de la Basura* can be downloaded at http://www.cientificosdelabasura.cl/cuentos.php where other materials for schoolteachers are also available (in Spanish).

Figura 1 - (A) Capa do livro que conta a história das viagens do personagem principal (o peixe jovem do sexo feminino chamado Jurella) com os seus amigos no sul Oceano Pacífico. Titulo traduzido: As Viagens de Jurella e os Microplásticos. (B) Uma das páginas do livro com a história ficcional na parte central e com alguns fatos na parte inferior. (C) Alunos lendo a história na sala de aula. (D) Manual para amostragem de microplásticos. Todas as histórias foram criadas por Cientificos de la Basura (Cientistas do Lixo) e podem ser baixadas em http://www.cientificosdelabasura.cl/cuentos.php onde também estão disponíveis (em espanhol) outros materiais para os professores.

Sampling marine litter and collecting data

Sampling strategies for marine litter are highly variable (*e.g.*, Ryan *et al.,* 2009; Hidalgo-Ruz *et al.,* 2012). Scientific sampling schemes for marine litter can be complex and might require expensive laboratory equipment. For example, sampling of very small microplastics (<1 mm) requires an infrared spectrometer in order to confirm the identity of the plastic particles. Clearly these kinds of sophisticated samplings and laboratory analyses are prohibitive for most citizen science projects. Straightforward sampling techniques and instantaneous data collection are desirable attributes for projects with schoolchildren (Braschler *et al.,* 2010), and compromises might have to be made between scientific goals and feasibility.

Herein, the basic tools were simple, consisting of marked ropes and sticks to delimit the sampling areas on the beach, and additionally sieves, trays and plastic bags for the microplastic study (figure 2). For all studies, there was a datasheet on which the data or the answers of interviewees were recorded (figure 2). Sampling was always done in groups of 2-6 schoolchildren, and teamwork was encouraged in the groups. For example, in the case of the interview survey, one kid read the questions while the other one wrote down the answers of the person that was interviewed (figure 2D).

Data evaluation, reflection, and communication of results

All data evaluation was done centrally at the home of the *Científicos de la Basura* at Universidad Católica del Norte in Coquimbo, Chile. Once all datasheets were received, these were carefully checked for incomplete or unreasonable data. In all cases the vast majority of the datasheets passed this quality control. In the case of the microplastics study, all samples were counted by the

Figure 2 - (A) Sampling for macroplastics. (B) Sieving of sand for microplastics. (C) Sorting of microplastics from material retained in the sieve. (D) Recording the answers of interviewees; one kid asked the questions, while the other wrote down the answers.

Figura 2 - (A) Amostragem de microplásticos. (B) Peneiração da areia para microplásticos. (C) Triagem de microplásticos no material retido na peneira. (D) Registrando as respostas dos entrevistados; um garoto fazia as perguntas, enquanto o outro escrevia as respostas.

schoolchildren, but they were asked to send the samples to our laboratory, where these were recounted. We found a good correlation between the numbers of microplastics reported by the schoolchildren and our recounts (Hidalgo-Ruz & Thiel, 2013).

Data evaluation was mainly descriptive, supported by graphs (figure 3). Graphics were kept as simple as possible, because the results were gathered in a study report that was shared with the teachers and also with the general public (figure 3). The results show that there is variation across the country, with highest amounts of litter and large proportions of samples with microplastics in the northern zone, where beach visitors are thought to be responsible for the majority of the litter on the beaches (figure 3).

Teachers were encouraged to reflect upon their results together with their class. While some teachers provided us with feedback, for the first two studies (marine litter and user perceptions) we did not know whether all teachers conducted this concluding activity. For the most recent study (microplastics), we therefore designed a brief activity that was done a few days after the microplastic sampling. Schoolchildren entered their data in an interactive website, and they could then generate simple bar graphs, which allowed them to compare their own results with those of the other participating schools.

Schoolchildren also responded to a brief survey about the activity and their perceptions of it. For example, after the microplastics study more than 70% of the schoolchildren admitted that before this activity they did not know about microplastics. Almost all of them (96%) expressed interest in participating in future environmental activities.

Participation in the projects also generated curiosity. Without explicitly soliciting it, we occasionally received questions that schoolchildren raised during the post-sampling reflection. Some teachers also asked the schoolchildren to write or draw about their experiences. Promoting independent inquiry is an important benefit of citizen science projects (Trumbull *et al.*, 2000), and this process should be encouraged during the class room reflections (Barab & Hay, 2001). Conferences where schoolchildren present their results are also considered highly valuable, because they allow the students to discuss their own data with others (Evans *et al.*, 2001).

Communication of results throughout educational establishments, local communities, and via scientific publications is the last part of the process and a crucial one. This provides a source of recognition that motivates young scientists to stay committed to the task over the years, which is necessary for long-term studies. For the research presented here, results were sent to the most prestigious and most widely read Chilean newspapers and were subsequently published with a high level of accuracy, becoming a point of pride and validation for all participants. The studies on marine litter (Bravo *et al.*, 2009), microplastics (Hidalgo-Ruz & Thiel, 2013), and beach user perception (Eastman *et al.*, 2013) were published in international journals, and publication of the other studies is presently in progress.

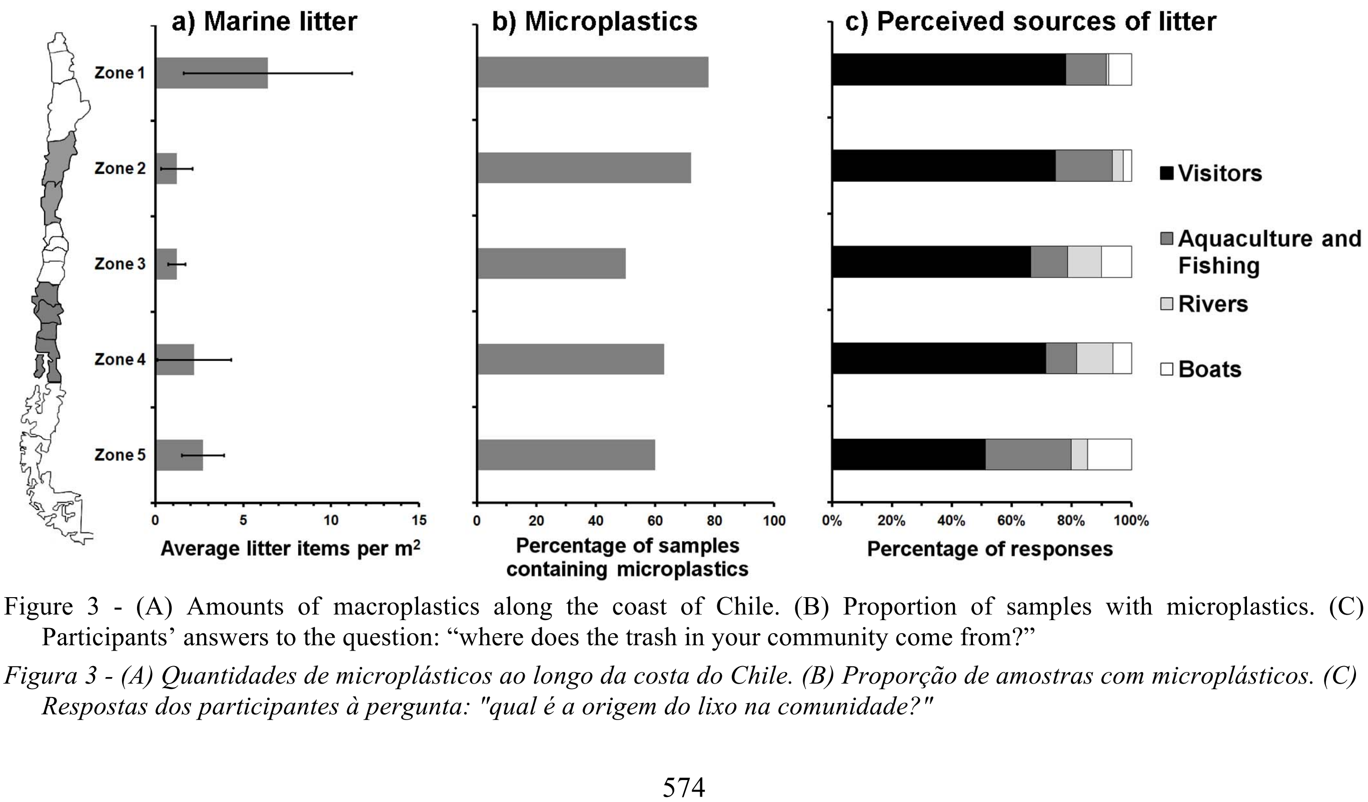

Figure 3 - (A) Amounts of macroplastics along the coast of Chile. (B) Proportion of samples with microplastics. (C) Participants' answers to the question: "where does the trash in your community come from?"

Figura 3 - (A) Quantidades de microplásticos ao longo da costa do Chile. (B) Proporção de amostras com microplásticos. (C) Respostas dos participantes à pergunta: "qual é a origem do lixo na comunidade?"

3. Discussion

Seven steps for a successful scientific study with schoolchildren

Our experience carrying out extensive research projects with young citizen scientists has led us to synthesize the process into a straightforward series of steps to follow to design a successful research project with school-children (Table 1), regardless of scientific field or habitat. To get started one must identify the research question, which should be expressed in plain words so as to be easily understood by the participating schoolchildren. After initial contact with interested teachers and scientific advisors, the project coordinators should frequently communicate with them – any scientific study supported by schoolchildren depends on the interest, knowledge and experience of the teacher! During an introductory class, schoolchildren are introduced to the study and they receive educational materials with background information. After reading the protocol with the question, the instructions, and data tables, the schoolchildren are familiarized with the sampling kit. On the sampling day, they are divided in groups, and each group carefully collects its samples and records them on the datasheet. At the end of the field sampling, the teacher gathers all completed datasheets, revises them for completeness, and then sends them to the research scientists together with eventual samples. Following the data evaluation, the research scientists share the principal results with the schoolchildren, which opens space for discussions and inquiry. This is also the opportunity to acknowledge each school with a certificate of participation and additional tokens. Teachers should also have the option to request the study data for their classes, e.g. science or math classes. The scientists leading the project should make an effort to publish the results in not only scientific publications but also local and national news media so as to recognize the citizen scientists' work. Any publications resulting from a study should be sent to the teachers and school direc

Table 1 - Seven steps required for the design of a successful research project supported by schoolchildren.

Tabela 1 - Sete etapas necessários para a elaboração de um projeto de pesquisa apoiado pelo sucesso escolar.

Seven steps	Description
(1) Identify question	Define a clear and simple question, expressing it in plain words. Answering this question should make a contribution to the advancement of scientific knowledge. Ensure that data sampling is inexpensive and can be conducted by schoolchildren.
(2) Recruit teacher and scientific advisor	Contact teacher and scientific advisor (a local professional with a relevant university degree), explain the objectives of the project, and describe the relevance of the study and the benefit for the schoolchildren. Generate specific instructions for the teacher, and make sure that (s)he prepares before the field sampling. Maintain frequent communication with the teacher, who is your most important ally.
(3) Motivate schoolchildren	Develop education materials and sampling protocols (with schemes and data tables) targeted to schoolchildren. Describe to them the importance of the project, making sure they understand that they will gather environmental data that will contribute to resolving a scientific question. Have tokens for each kid, e.g. storybooks, caps, calendars, notepads, pencils, and/or awards for groups or the entire course.
(4) Do the sampling	On the way to the sampling site or the day before the activity, schoolchildren re-read the protocol. At the site, schoolchildren are divided into teams, each receiving its own sampling tools. Within each team, some kids take samples or read interviews, while others record the data. The teacher and the scientific advisor are available to answer questions. At the end of the field sampling, the teacher gathers the completed data sheets.
(5) Reflect about sampling	Back in the class room the schoolchildren reflect about the event; the teacher raises questions that promote independent inquiry (Examples: Did you expect so much litter? Where did the litter come from? What ecological impact does the litter cause? Do you think that other schools will have different results? Why?).
(6) Gather and evaluate data	Request that all teachers collect the datasheets, check them for correct identification, and mail the originals to you immediately after the event. Remind teachers and use this opportunity to thank them for their participation. Generate descriptive statistics of your data that show the key results in straightforward terms.
(7) Communicate results to schoolchildren and public	Prepare simple graphics that can be easily understood by schoolchildren. Integrate these results in a news bulletin that is available on the website or printed. Send this to the school together with a certificate of participation and tokens of appreciation. Keep teachers and students informed if the study is publicized in the news media or in a scientific publication so as to recognize their hard work.

tors, who then may share them with the participating schoolchildren (depending on the time lag between the study and publication date).

Schoolchildren supporting environmental research

Our experiences showed that schoolchildren (grades 5 - 11) are able to follow simple sampling instructions and to collect environmentally relevant data. Results from another citizen science project that required correct identification of two invasive crab species showed that very young schoolchildren (grade 3) achieved 80% correct identification, while older schoolchildren (grade 7) correctly identified the crabs in more than 95% of the cases (Delaney *et al.*, 2008). In a project on intertidal rocky shorelines, schoolchildren from grades 7 to 12 counted emblematic organisms such as purple seastars with the same precision as well-trained university scientists (Osborn *et al.*, 2005). Estimates by school-children (grades 3 – 10) of white oak stands coincided with those of professionals (Galloway *et al.*, 2006). In another study, schoolchildren (grades 1 – 8) counted mule deer and elk reliably along their daily schoolbus routes (Galloway *et al.*, 2011). For water samples taken and analyzed by schoolchildren (grades 5 - 12), there was a good correlation with the values obtained by professionals (Peckenham *et al.*, 2012). These examples show that schoolchildren can collect useful environmental data when receiving well-designed instructions (see also Rock & Lauten, 1996). The schools participating in our program come from highly variable backgrounds (all economic levels; rural and urban schools) and also the family background of schoolchildren varied widely within each class. In order to overcome possible problems, we asked the teachers to assemble the working groups adequately, i.e. ensuring that each group had one academically strong student and one student with positive leadership abilities.

Working with schoolchildren on citizen science projects can have many advantages, including wide spatial coverage (if many schools are involved), regular sampling (annual schedules) and competent supervisors (university-trained teachers). However, several aspects need to be kept in mind. The motivational level of schoolchildren and teachers might initially not be as high as that of many other citizen science groups, such as bird watchers, flower friends, and others. Most citizen scientists are highly motivated volunteers, and while this initially might not be the case for schoolchildren they are curious to learn about their environment and can be easily motivated.

Any citizen science project should also give something back to the participating citizens (Silvertown, 2009). This is especially the case for projects with schoolchildren. Educational material and simple sampling tools (e.g. a magnifying glass, forceps, or a notepad), which each participating schoolchild obtains as a personal token can have a lasting impact, especially when it can be shared with others, e.g. a book or a tool (Galloway *et al.*, 2011). The most important reward for the schoolchildren is the contact with a scientific project and with the research scientists (Braschler *et al.*, 2010). Seeing that they contribute information and help solve a scientific question can be very motivating for the schoolchildren. It is thus instrumental that the scientists return the results from their study to the schoolchildren (Hochachka *et al.*, 2012). We recommend preparing a concise news bulletin (published in print or on a website) that describes the main result of the study in clear and plain language, supported by a figure and a photograph. This information can also be shared with local and national news media, thus making the students feel part of an important network of young scientists and reinforcing camaraderie.

It is important to note that the long-term success of citizen science projects with schoolchildren depends on the teachers and school directors (Weckel *et al.*, 2010). Frequent interactions with them are important (Osborn *et al.*, 2005) and having in-person interaction, whether with the research scientists or local scientific advisors, can help maintain their interest and technical expertise. Coordinators of citizen science projects should also listen to the teachers who best know their schoolchildren, what they can and like to contribute, and also what they – as educators – would expect from a program (Evans *et al.*, 2001; Brewer, 2002; Baumgartner *et al.*, 2006). While standardized data are important for scientific studies, instructions should be sufficiently flexible such that teachers can adjust them to their course curricula (Spencer *et al.*, 1998). Enthusiastic teachers might even incorporate aspects from the project into their course programs and further develop the project beyond questions initially designed by research scientists (see e.g. Osborn *et al.*, 2005). Because long-term scientific questions require repetition of procedures year after year, to keep teachers engaged in the process intermediate goals and rewards could be set for the teacher to ensure long-term commitment.

Schoolchildren doing environmental science – an opportunity for coastal managers

Many scientific studies require large-scale sampling of basic environmental data. This poses enormous challenges to small research teams. At the same time schoolchildren learn scientific methods in the classroom, receiving elemental training in recognizing species or measuring environmental parameters such as temperature or pH. Similar science curricula are covered in schools throughout the world, and identical topics are taught to new students every year. This offers a great opportunity because schoolchildren can collect meaningful data that would not be available otherwise. Several citizen science projects (including those described and discussed here) have shown that with specific instructions schoolchildren are capable of gathering reliable data. Based on these considerations we encourage research scientists and school teachers to form alliances in the quest for gathering large-scale and long-term environmental data (see also Kolok & Schoenfuss, 2011).

These alliances have produced practical management results. A review of marine citizen science studies showed that a principal focus of this work has been to inform management decisions (Thiel *et al.*, 2014). A study using data gathered in a schoolkid survey project in Chile (Eastman *et al.*, 2013) regarding beach users was cited by the Chilean Senate as part of a law proposal to fine those who litter on beaches (Senado de Chile, 2012). Another citizen science survey of marine debris in central California directly influenced a ban on Styrofoam take-out containers from local municipalities (Rosevelt *et al.*, 2013).

In addition to generating scientific information, schoolchildren learn about their environment and the scientific process (Osborn *et al.*, 2005; Weckel *et al.*, 2010). Gathering ecological data and reflecting about the results also raises environmental awareness (Braschler, 2009) and can connect children to nature in a way that lasts a lifetime (Sagarin and Pauchard, 2012). This is especially relevant because this approach reaches broad demographic groups (as opposed to birders, for example), and schoolchildren can transmit their new knowledge and enthusiasm to their families who also may not have contact with the scientific or environmental fields, multiplying the societal benefit of these programs. Working with schoolchildren poses specific challenges to research scientists because instructions need to be targeted towards the training background of these young citizen scientists. However, the rewards are manyfold as enthusiastic schoolchildren are ideal ambassadors for the scientific cause.

Acknowledgements

We thank all the teachers and schoolchildren who have participated over the years in this project. Guillermo Luna-Jorquera and Enrique Martínez provided helpful comments on an initial draft of this manuscript. Funding was received by the program CONICYT-EXPLORA of the Chilean Science Foundation. MT was supported by the Chilean Millennium Initiative (grant NC120030).

References

Barab, S.A.; Hay, K.E. (2001) – Doing science at the elbows of experts: Issues related to the science apprenticeship camp. *Journal of Research in Science Teaching*, 38(1):70–102. DOI: 10.1002/1098-2736(200101)38:1<70::AID-TEA5>3.3.CO;2-C

Barnes, D.K.A.; Galgani, F.; Thompson, R.C.; Barlaz, M. (2009) – Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B,* 364:1985–1998. DOI: 10.1098/rstb.2008.0205

Baumgartner, E.; Duncan, K.M.; Handler, A.T. (2006) – Student–scientist partnerships at work in Hawaii. *Journal of Natural Resources and Life Sciences Education,* 35:72–78. DOI: 10.2134/jnrlse2006.0072

Beaubien, E.G.; Hamann, A. (2011) – Spring flowering response to climate change between 1936 and 2006 in Alberta, Canada. *BioScience,* 61(7):514–524. DOI: 10.1525/bio.2011.61.7.6

Boerger, C.M.; Lattin, G.L.; Moore, S.L.; Moore, C.J. (2010) – Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. *Marine Pollution Bulletin,* 60(12):2275–2278. DOI: 10.1016/j.marpolbul.2010.08.007

Bonney, R.; Cooper, C.B.; Dickinson, J.; Kelling, S., Phillips, T.; Rosenberg, K.V.; Shirk, J. (2009) – Citizen science: A developing tool for expanding science knowledge and scientific literacy. *BioScience,* 59(11):977–984. DOI: 10.1525/bio.2009.59.11.9

Bonney, R.; Shirk, J.L.; Phillips, T.B.; Wiggins, A.; Ballard, H.L.; Miller-Rushing, A.J.; Parrish, J.K. (2014) – Next steps for citizen science. *Science,* 343(6178):1426–1437. DOI: 10.1126/science.1251554

Braschler, B. (2009) – Successfully implementing a citizen-scientist approach to insect monitoring in a resource-poor country. *BioScience,* 59(2):103–104. DOI: 10.1525/bio.2009.59.2.2

Braschler, B.; Mahood, K.; Karenyi, N.; Gaston, K.J.; Chown, S.L. (2010) – Realizing a synergy between research and education: how participation in ant monitoring helps raise biodiversity awareness in a resource-poor country. *Journal of Insect Conservation,* 14(1):19–30. DOI: 10.1007/s10841-009-9221-6

Bravo, M.; de los Ángeles Gallardo, M.; Luna-Jorquera, G.; Núñez, P.; Vásquez, N.; Thiel, M. (2009) − Anthropogenic debris on beaches in the SE Pacific (Chile): Results from a national survey supported by volunteers. *Marine Pollution Bulletin,* 58(11):1718−1726. DOI: 10.1016/j.marpolbul.2009.06.017

Brewer, C. (2002) – Conservation education partnerships in schoolyard laboratories: A call back to action. *Conservation Biology,* 16(3):577–579. DOI: 10.1046/j.1523-1739.2002. 01633.x

Davies, T.K.; Stevens, G.; Meekan, M.G.; Struve, J.; Rowcliffe, J.M. (2012) – Can citizen science monitor whale-shark aggregations? Investigating bias in mark–recapture modelling using identification photographs sourced from the public. *Wildlife Research,* 39(8):696–704. DOI: 10.1071/WR12092

Davison, P.; Asch, R.G. (2011) – Plastic ingestion by mesopelagic fishes in the North Pacific Subtropical Gyre. *Marine Ecology Progress Series,* 432:173–180. DOI: 10.3354/meps09142

Delaney, D.G.; Sperling, C.D.; Adams, C.S.; Leung, B. (2008) – Marine invasive species: Validation of citizen science and implications for national monitoring networks. *Biological Invasions,* 10(1):117–128. DOI: 10.1007/s10530-007-9114-0

Devictor, V.; Whittaker, R.J.; Beltrame, C. (2010) – Beyond scarcity: Citizen science programmes as useful tools for conservation biogeography. *Diversity and Distributions,* 16(3):354–362. DOI: 10.1111/j.1472-4642.2009.00615.x

Dickinson, J.; Zuckerberg, B.; Bonter, D.N. (2010) – Citizen science as an ecological research tool: Challenges and benefits. *Annual Review of Ecology, Evolution, and Systematics,* 41:149–172. DOI: 10.1146/annurev-ecolsys-102209-144636

Eastman, L.B.; Núñez, P.; Crettier, B.; Thiel, M. (2013) – Identification of self-reported user behavior, education level, and preferences to reduce littering on beaches – A survey from the SE Pacific. *Ocean & Coastal Management,* 78:18–24. DOI: 10.1016/j.ocecoaman.2013.02.014

Evans, C.A.; Abrams, E.D.; Rock, B.N.; Spencer, S.L. (2001) – Student/scientist partnerships: A teachers' guide to evaluating the critical components. *The American Biology Teacher,* 63(5):318–323. DOI: 10.1662/0002-7685(2001)063[0318:SSP]2.0.CO;2

Fernández, M.; Jaramillo, E.; Marquet, P.A.; Moreno, C.A.; Navarrete, S.A.; Ojeda, F.P.; Valdovino, C.R.; Vásquez, J.A. (2000) – Diversity, dynamics and biogeography of Chilean benthic nearshore ecosystems: an overview and guidelines for conservation. *Revista Chilena de Historia Natural,* 73(4):797–830. Available on-line at: http://www.scielo.cl/pdf/rchnat/v73n4/art21.pdf

Galloway, A.W.E.; Tudor, M.T.; Vander Haegen, W.M. (2006) – The reliability of citizen science: A case study of Oregon white oak stand surveys. *Wildlife Society Bulletin,* 34(5):1425–1429. DOI: 10.2193/0091-7648(2006)34[1425:TROCSA]2.0.CO;2

Galloway, A.W.E.; Hickey, R.J.; Koehler, G.M. (2011) – A survey of ungulates by students along rural school bus routes. *Society and Natural Resources: An International Journal,* 24(2):201–204. DOI: 10.1080/08941920903222572

Gregory, M.R. (2009) – Environmental implications of plastic debris in marine settings – Entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society B,* 364:2013–2025. DOI: 10.1098/rstb.2008.0265

Hidalgo-Ruz, V.; Gutow, L.; Thompson, R.C.; Thiel, M. (2012) – Microplastics in the marine environment: A review of the methods used for identification and quantification. *Environmental Science and Technology,* 46(6):3060–3075. DOI: 10.1021/es2031505

Hidalgo-Ruz, V.; Thiel, M. (2013) – Distribution and abundance of small plastic debris on beaches in the SE Pacific (Chile): A study supported by a citizen science project. *Marine Environmental Research,* 87-88:12–18. DOI: 10.1016/j.marenvres.2013.02.015

Hochachka, W.M.; Fink, D.; Hutchinson, R.A.; Sheldon, D.; Wong, W.K.; Kelling, S. (2012) – Data-intensive science applied to broad-scale citizen science. *Trends in Ecology and Evolution,* 27(2):130–137. DOI: 10.1016/j.tree.2011.11.006

Ivar do Sul, J.A.; Costa, M.F. (2007) – Marine debris review for Latin America and the wider Caribbean region: from the 1970s until now, and where do we go from here? *Marine Pollution Bulletin,* 54(8):1087–1104. DOI: 10.1016/j.marpolbul.2007.05.004

Kolok, A.S.; Schoenfuss, H.L. (2011) – Environmental scientists, biologically active compounds and sustainability: The vital role for small-scale science. *Environmental Science and Technology,* 45(1):39–44. DOI: 10.1021/es100455d

Kolok, A.S.; Schoenfuss, H.L.; Propper, C.R.; Vail, T.L. (2011) – Empowering citizen scientists: The strength of many in monitoring biologically active environmental contaminants. *BioScience,* 61(8):626–630. DOI: 10.1525/bio.2011.61.8.9

Maximenko, N., Hafner, J.; Niiler, P. (2012) – Pathways of marine debris derived from trajectories of Lagrangian drifters. *Marine Pollution Bulletin,* 65(1-3):51–62. DOI: 10.1016/j.marpolbul.2011.04.016

Moore, C.J. (2008) – Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. *Environmental Research,* 108(2):131–139. DOI: 10.1016/j.envres.2008.07.025

Osborn, D.A.; Pearse, J.S.; Roe, C.A. (2005) – Monitoring rocky intertidal shorelines: A role for the public in resource management. *In:* O. T. Magoon, H. Converse, B. Baird, B. Jines & M. Miller-Henson (eds.), *California and the World Ocean '02, Conference Proceedings*, pp. 624-636, American Society of Civil Engineers, Reston, VA, USA. DOI: 10.1061/40761(175)57

Peckenham, J.M.; Thornton, T.; Peckenham, P. (2012) – Validation of student generated data for assessment of groundwater quality. *Journal of Science Education and Technology,* 21(2):287–294. DOI: 10.1007/s10956-011-9317-0

Pruter, A.T. (1987) – Sources, quantities and distribution of persistent plastics in the marine environment. *Marine Pollution Bulletin,* 18(6, suppl.B):305–310. DOI: 10.1016/S0025-326X(87)80016-4

Rock, B.N.; Lauten, G.N. (1996) – K-12 Grade students as active contributors to research investigations. *Journal of Science and Technology,* 5(4):255–266. DOI: 10.1007/BF01677123

Rosevelt, C.; Los Huertos, M.; Garza, C.; Nevins, H.M. (2013) – Marine debris in central California: Quantifying type and abundance of beach litter in Monterey Bay, CA. *Marine Pollution Bulletin,* 71(1-2):299–306. DOI: 10.1016/j.marpolbul.2013.01.015

Ryan, P.G.; Moore, C.J.; van Franeker, J.A.; Moloney, C.L. (2009) – Monitoring the abundance of plastic debris in the marine environment. *Philosophical Transactions of the Royal Society B,* 364:1999–2012. DOI: 10.1098/rstb.2008.0207

Sagarin, R.; Pauchard, A. (2012) – *Observation and ecology: broadening the scope of science to understand a complex world*. Island Press. ISBN: 978-1597268264. DOI: 10.5822/978-1-61091-230-3.

Senado de Chile (2012) - Quienes ensucien o dañen playas, ríos y lagos deberán realizar un mínimo de 15 días de trabajos comunitarios (Proyecto de ley). Senado de Republica de Chile, Boletín 8179-07, Valparaíso, Chile. Available on-line at http://www.senado.cl/quienes-ensucien-o-danen-playas-rios-y-lagos-deberan-realizar-un-minimo-de-15-dias-de-trabajos-comunitarios/prontus_senado/2012-03-09/121332.html

Silvertown, J. (2009) – A new dawn for citizen science. *Trends in Ecology and Evolution,* 24(9):467–471. DOI: 10.1016/j.tree.2009.03.017

Spencer, S.; Huczek, G.; Muir, B. (1998) – Developing a student-scientist partnership: Boreal forest watch. *Journal of Science Education and Technology,* 7(1):31–43. DOI: 10.1023/A:1022532131864

Teuten, E.L.; Saquing, J.M.; Knappe, D.R.; Barlaz, M.A.; Jonsson, S.; Bjorn, A.; Rowland, S.J.; Thompson, R.C.; Galloway, T.S.; Ymashita, R.; Ochi, D.; Waanuki, Y.; Moore, C.; Viet, P.H.; Tana, T.S.; Prudente, M.; Boonyatumanond, R.; Zakaria, M.P.; Akkhavong, K.; Ogata, Y.; Hirai, H.; Iwasa, S.; Mizukawa, K.; Hagino, Y.; Imamura, A.; Saha, M.; Takada, H. (2009) – Transport and release of chemicals from plastics to the environment and to wildlife. *Philosophical Transactions of the Royal Society B,* 364:2027–2045. DOI: 10.1098/rstb.2008.0284

Thiel, M.; Hinojosa, I.; Vásquez, N.; Macaya, E. (2003) – Floating marine debris in coastal waters of the SE-Pacific (Chile). *Marine Pollution Bulletin,* 46(2):224–231. DOI: 10.1016/S0025-326X(02)00365-X

Thiel, M.; Macaya, E.C.; Acuña, E.; Arntz, W.E.; Bastías, H.; Brokordt, K.; Camus, P.; Castilla, J.C.; Castro, L.R.; Cortés, M.; Dumont, C.P.; Escribano, R.; Férnandez, M.; Gajardo, J.A.; Gaymer, C.F.; Gomez, I.; González, A.E.; González, H.E.; Haye, P.A.; Illanes, J.E.; Iriarte, J.L.; Lancellotti, D.A.; Luna-Jorquera, G.; Luxoro, C.; Manriquez, P.H.; Marín, V.; Muñoz, P.; Navarrete, S.A.; Peréz, E.; Poulin, E.; Sellanes, J.; Sepulveda, H.H.; Stotz, W.; Tala, F.; Thomas, A.; Vargas, C.A.; Vasquez, J.A.; Vega, J.M.A. (2007) – The Humboldt current system of northern and central Chile: Oceanographic processes, ecological interactions and socioeconomic feedback.

Oceanography and Marine Biology: An Annual Review (ISSN: 0078-3218), 45:195–344. Available on-line at http://figema.cl/online /pdf/OceanogrMarBiolAnnuRev_45_195_344.pdf

Thiel, M.; Bravo, M.; Hinojosa, I.A.; Luna, G.; Miranda, L.; Núñez, P.; Pacheco, A.S.; Vásquez, N. (2011) – Anthropogenic litter in the SE Pacific: an overview of the problem and possible solutions. *Journal of Integrated Coastal Zone Management,* 11(1):115-134. DOI: 10.5894/rgci207

Thiel, M.; Penna-Díaz, M.P.; Luna-Jorquera, G.; Salas, S.; Sellanes, J.; Stotz, W. (2014) – Citizen scientists and marine research: volunteer participants, their contributions, and projection for the future. *Oceanography and Marine Biology: An Annual Review,* 52:257–314.

Thompson, R.C.; Moore, C.J.; vomSaal, F.S.; Swan, S.H. (2009) – Plastics, the environment and human health: Current consensus and future trends. *Philosophical Transactions of the Royal Society B,* 364:2153–2166. DOI: 10.1098/rstb.2009.0053

Trumbull, D; Bonney, R.; Bascom, D.; Cabral, A. (2000) – Thinking scientifically during participation in a citizen-science project. *Science Education,* 84(2):265–275. DOI: 10.1002/(SICI)1098-237X(200003)84:2<265::AID-SCE7>3.0.CO;2-5

Villegas, J.C.; Morrison, C.T.; Gerst, K.L.; Beal, C.R.; Espeleta, J.E.; Adamson, M. (2010) – Impact of an ecohydrology classroom activity on middle school students' understanding of evapotranspiration. *Journal of Natural Resources and Life Sciences Education,* 39(1):150–156. DOI: 10.4195/jnrlse. 2009.0044k

Weckel, M.E.; Mack, D.; Nagy, C.; Christie, R.; Wincorn, A. (2010) – Using citizen science to map human-coyote interaction in suburban New York, USA. *Journal of Wildlife Management,* 74(5):1163–1171. DOI: 10.2193/2008-512

Williams, A.T.; Simmons, S.L. (1997) – Estuarine litter at the river/beach interface in the Bristol Channel, United Kingdom. *Journal of Coastal Research,* 13(4):1159–1165. Article Stable URL: http://www.jstor.org/stable/4298724

Worthington, J.; Silvertown, J.; Cook, L.; Cameron, R.; Dodd, M.; Greenwood, R.; McConway, K.; Skelton, P. (2011) – Evolution MegaLab: A case study in citizen science methods. *Methods in Ecology and Evolution,* 3(2):303-309. DOI: 10.1111/j.2041-210X.2011.00164.x