COLONIZATION PATTERNS OF INVERTEBRATES IN TEMPORARY STREAM SYSTEMS ON MOOREA, FRENCH POLYNESIA

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Abstract. Invertebrates house a large proportion of the Earth's biodiversity and play key ecological roles as primary consumers, nutrient cyclers, and prey for predators. Temporary streams are defined by a cessation in surface water flow and make up a substantial proportion of stream systems worldwide. Temporary streams are distinctively colonized by both aquatic and terrestrial invertebrates. Aquatic and terrestrial invertebrates were sampled during both the dry and flowing phase from four temporary stream sites on Moorea, French Polynesia. The diversity of terrestrial invertebrates increased over time in dry channels and decreased when the streams were flowing; aquatic invertebrates were present in flowing streams the same day they began to flow. Soil divots from temporary stream sites were experimentally inundated with water to determine whether or not aquatic invertebrates seek refuge from desiccation within stream substrates. No aquatic invertebrates emerged from soil samples after being rehydrated for 5 weeks. These findings indicate that aquatic invertebrates with desiccation-resistant stages may not be prevalent on Moorea, and provide a baseline understanding of invertebrate community dynamics that should be monitored in the future as climate change may impact temporary stream systems.

Key words: terrestrial invertebrates; aquatic invertebrates; temporary streams; soil rehydration; desiccation-resistance; colonization; dispersal; Moorea, French Polynesia

INTRODUCTION

Surface freshwater habitats only constitute 0.01% of the Earths total water and cover only about 0.8% of the Earth's surface, yet they are home to approximately 126,000 animal species—approximately 9.5% of the total number of animal species recognized worldwide (Gleick 1996; Balian et al. 2008). The majority of these species are Insecta (60.4%), followed by Vertebrates (14.5%), Crustaceans (10%), Arachnids (5%), Mollusks (4%), Rotifera (1.6%), Annelida (1.4%), and Nematoda (1.4%), while the remainder are minor groups including Platyhelminths and Collemboa (Balian et al. 2008). Invertebrates are thus integral to freshwater ecosystems because they comprise most of the freshwater fauna. As consumers in intermediate trophic levels, freshwater invertebrates play key roles as nutrient cyclers, primary consumers, decomposers, translocators of nutrients, and prey for fish (Wallace and Webster 1996). Furthermore, freshwater invertebrates constitute a major food source for terrestrial and riparian consumers such as spiders, birds, bats, and lizards (Baxter et al. 2005).

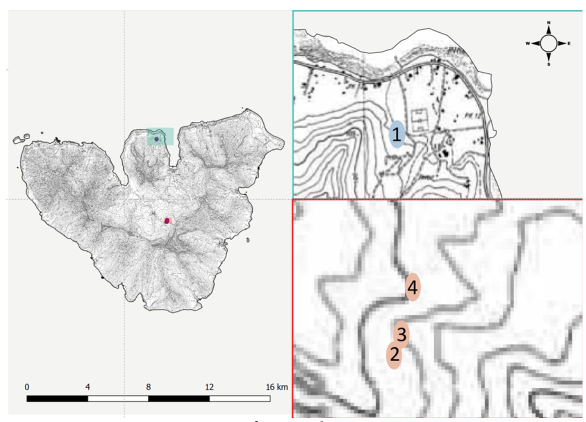

FIG. 1. Map of study sites on Moorea, French Polynesia. Layers courtesy of the Geospatial Innovation Facility, University of California Berkeley.

Since aquatic, riparian, and terrestrial zones are all interconnected, terrestrial invertebrates play a similarly important role in aquatic ecosystems. Aquatic invertebrate consumers feed on small terrestrial invertebrates and larvae (Townsend and Hildrew 1979). Additionally, many fish species depend heavily on terrestrial invertebrate

TABLE 1. The latitude and longitude in degrees minutes, elevation in meters, and stream width in meters for all four study sites.

Site	1	2	3	4
Latitude (S)	17°29.432'	17°32.374′	17°32.368′	17°32.315′
Longitude (W)	149°49.892′	149°49.559′	149°49.555′	149°49.542′
Elevation (m)	0	242	238	240
Stream Width (m)	3.12	2.55	1.43	1.3

inputs which are responsible for up to 50% of their annual diet (Nakano and Murakami 2001).

A large proportion of the world's stream networks are considered temporary (Stubbington et al. 2017). Temporary streams are characterized by a cessation of surface water flow, becoming partially or completely dry (Leigh et al. 2016). They are classified as "intermittent" when ground water levels drop below the stream bed during seasonal changes and "ephemeral" when initiated solely by precipitation (Uys & O'Keeffe, 1997). In temporary stream systems the distinctions between terrestrial, riparian, and aquatic habitats can be unclear. Since temporary stream ecosystems undergo varying wet and dry phases, the biota that inhabit these systems are highly specialized. To avoid desiccation after surface flow ceases, invertebrates either disperse to neighboring permanent habitats, or seek shelter in saturated soil in active or dormant physiological states; while others simply die off (Velasco and Millán 1998; Tronstad et al. 2005). Conversely, terrestrial invertebrates, such as arthropods, quickly colonize dry stream beds, which has cascading effects on both terrestrial and riparian invertebrate assemblages (Sánchez-Montoya et al. 2016a). Therefore, invertebrates that inhabit temporary streams play an essential role in aquatic, riparian, and terrestrial ecosystems as vital parts of each food web (Stubbington et al. 2017).

While temporary streams have received increased attention in recent years, the species diversity of temporary streams on tropical oceanic islands is still relatively understudied (Dudgeon et al. 2006). French Polynesia has two seasons—the wet season from November to April and the dry season from May to October (Hopuare et al. 2015). The high amount of rainfall during the wet season is caused by the islands' location within the South Pacific Convergence Zone (SPCZ), as well as orographic precipitation influenced by the humid trade winds (Hopuare et al. 2015). Highly variable annual precipitation and thus fluctuating terrestrial water flow makes Moorea an ideal island to study temporary streams and their fauna.

The purpose of the present study was to characterize the colonization patterns of invertebrates in temporary streams after the surface flow stopped and once flow resumed. Soil divots from dry stream beds were rehydrated to determine if desiccation-resistant invertebrates played a significant role in recolonizing streams after surface flows were activated. I hypothesized that greater invertebrate fauna diversity is associated with increased time in a dry or flowing phase. Additionally, I hypothesized that soils rehydrated with greater amounts of water will yield quicker invertebrate emergence.

METHODS

Study site

Moorea is a volcanic island (134km^2) located in the Pacific Ocean, and is one of the 14 islands that constitute the Society Islands in French Polynesia. The average annual temperature in Moorea varies from 25-30 degrees Celsius with precipitation on Moorea ranging from 200-400cm per year (Resh et al. 1990).

This study was conducted along four different temporary streams on Moorea (Fig. 1). The first site is located approximately 2km north of the Richard B. Gump Research Station, and is accessed by walking inland on the road just before the large bridge that crosses over the mouth of the river. Sites 2-4 are all part of the Opunohu River Catchment and lie along the Three Pines Trail that begins at the Belvedere lookout. The specific coordinates, elevation, and width of each stream site are located in Table 1.

Soil divots were subject to rehydration for a span of five weeks from October 11, 2017 to

November 15, 2017. Sampling of invertebrates in dry streambeds occurred for two weeks immediately after all streams had stopped flowing; the invertebrate community was sampled in flowing streams for one week after heavy precipitation activated surface flow for all streams.

Invertebrate survey

Each site was sampled every other day during the study period, unless a large storm event occurred, in which case sites were revisited the following day to check if there was a change from dry to flowing. When the stream beds were dry, two different methods to collect terrestrial invertebrates were utilized. Pitfall traps have been extensively used to capture ground-dwelling invertebrates using the relative abundance of different organisms as a proxy for community composition as a whole (Wishart 2000; Datry et al. 2012; Sánchez-Montoya et al. 2016a). Despite various potential biases, including catching predominantly fast-moving taxa, the potential for organisms to escape from traps, and the potential to lose samples to predation, pitfall traps have been shown to be far superior to quadrat sampling (Wishart 2000, Corti et al. 2013). The pitfall traps implemented were plastic cups that measured 6cm in diameter and 10cm in length. Five pitfall traps were placed with the top flush with the ground, spaced 2m apart (starting downstream and moving upstream) at haphazard locations across the width of the stream bed. A 1:2:2 mixture of salt, detergent, and water was poured into the pitfall traps to a level of 4cm, in order to prevent invertebrates from escaping and preserve them. Large Tupperware lids were placed slightly above the pitfall traps, supported by surrounding rocks and wood debris, to ensure that precipitation did not flood the traps, while still allowing invertebrates to enter. Pitfall traps were emptied every 48 hours into sealed containers and then refilled. Collections from pitfall traps were sieved through 0.125mm mesh and invertebrates were isolated for later identification.

Hand sampling methods were also used to collect a more complete assemblage of invertebrates. Sampling occurred in the same 10m stretch where pitfall traps were placed. 15 minute timed searches were executed in varied sections of the dry streambed—beneath rocks, leaves, streamside vegetation and wood debris. Invertebrates were collect with forceps and placed into sealed containers. Organisms from both sampling methods were preserved in 70% ethanol and later identified to the lowest taxonomic resolution possible.

When temporary streams were flowing, two sampling methods, as adapted from Resh et al (1990), were also performed. A 500mm D-frame net was used to sample the benthic invertebrate community in various stream habitats including runs, pools, and riffles. The surfaces of stones and large wood debris were also scraped into the net. D-frame sampling occurred for 10 minutes. Additionally, 5 minute searches with a small aquarium net were conducted in areas of rapid-flow in order to capture invertebrates in the water column. In-stream rocks and other debris were also inspected.

All samples containing organisms were sieved with 0.125mm mesh, sorted and identified using a dissecting microscope, and preserved in 70% ethanol. Sieved soil and other debris from both the dry streambed and flowing stream were searched for invertebrates in the lab for a total of 20 minutes for each sample.

Invertebrate identifications involved consulting regional databases and literature including the Moorea Biocode Database (Moorea Biocode Project 2010), the Cook Islands Biodiversity Database (Cook Islands Biodiversity Database 2007), The Insects of Tahiti (Paulian 1998), and specialist determinations (see acknowledgments).

Rehydration experiment

At each of the four sites, seven soil divots were collected. Divots were taken 2m apart and at haphazard areas along the width of the stream bed. Samples were collected from a depth of 25cm in attempts to reach moist soil near the hyporheic zone. All soil samples collected were moderately moist. Plastic cups (measuring 11cm in diameter and 16cm in depth) were filled with 10cm of soil. Rocks exceeding 5cm in length were removed from the soil samples.

One soil sample from each site was initially sieved through 4mm, 2mm, and 0.125mm mesh openings to look for live organisms, eggs, and larvae present without rehydration. Three soil divots were rehydrated with water such that the water level was 1cm above the soil. The remaining three soil divots were filled so water levels were 5cm above the soil. Each container was outfitted with fine mesh on the top to allow for air flow, yet prevent invertebrates from escaping and alien invertebrates from entering.

Water was changed every other day, and the discarded water column was visually inspected and viewed with microscopy to detect invertebrates. Soil cores of 2.5cm in diameter were taken from rehydrated samples weekly in order to identify invertebrates within the soil. These soil cores were run through 4mm, 2mm, and 0.125mm sieves. All samples were placed outside during the rehydration experiment to emulate typical day-night light cycles with a uniform amount of canopy cover.

Statistical analysis

Invertebrates found in the survey were classified as terrestrial or aquatic species. A linear regression was used to test for a relationship between days the streambed was dry or days the stream was flowing and total species diversity calculated with Shannon's Diversity Index. A linear regression was also used to test for a relationship between the days elapsed when the stream was dry or flowing and total species richness. The average Shannon's diversity across all sites was calculated for aquatic and terrestrial invertebrates and plotted across days. The Bray-Curtis distance measure was calculated using species abundance data and was represented using a non-metric multi-dimensional scaling (NMDS) plot. A permutational analysis of variance (PERMANOVA) was used to compare whether or not invertebrate communities significantly differed by site and by flow-phase (flowing versus dry). Post hoc analyses were performed to see which stream sites differed from each another. All statistical tests were conducted in R (R Core Team, 2017). The "dplyr" and "vegan" and R packages were used for analyses as well as the "pairwise.adonis" function (Arbizu 2016; Oskanen et al. 2017; Wickham et al. 2017). The "ggplot2" package was used to visualize the data (Wickham 2009)

RESULTS

Invertebrate survey

A total of 45 different taxa were found across the four temporary stream study sites during both the wet and dry phases; 24 were unique to dry streambeds, 9 were unique to flowing streams, and 14 were present both in dry streambeds and flowing streams.

Of the organisms collected, the vast majority were Arthopods (91%), with minor contributions from Mollusks (4.6%), Annelids (3.6%), and Platyhelminths (>1%). 85% of the individuals sampled were terrestrial organisms. 66% of the individuals were collected from dry streambeds, while 33% were collected from flowing streams. Appendix A shows a list of all organisms collected.

Dry Phase:

The duration of days that the stream bed was dry had a significant positive effect on species diversity as well as species richness for all four sites (Fig. 2a-h). Terrestrial arthropods including *Glyphiulus granulatus, Orthomorpha coarctata, Leptogoniulus sorornus, Cubaris murina,* and family Formicidae were the present in all dry streambeds within a day after the stream stopped flowing. These taxa were also among the most abundant found across the sampling period, comprising 65% of the total invertebrates sampled in dry channels. A diverse range of Insecta from the orders Diptera, Coleoptera, Lepidoptera, Hymenoptera, Blattodae, Hemiptera, Psocoptera, Dermaptera, and Orthoptera were found in dry streambeds. Diptera from the families Drosophilidae, Sarcophagidae, and Chloropidae consistently colonized dry streambeds 3-5 days after surface water flow ceased. The highest average diversity across all sites was on day 14 where the average Shannon Diversity was 2.2 with a standard deviation of 0.1 (Fig 3).

Wet Phase:

The duration of days that the stream bed was flowing had no significant effect on the total species diversity or species richness for all four sites (Fig. 2i-p). When the streams switched from dry to flowing, a substantial number of terrestrial invertebrates were found in the flowing stream. On day 16 (the first day all streams began to flow), the average Shannon Diversity for terrestrial invertebrates was 1.89 with a standard deviation of $5.1\text{x}10^{-2}$ (Fig. 3). *Glyphiulus granulatus, Orthomorpha coarctata, Talorchestia rectimana,* family Formicidae and Acari accounted for 56% of the terrestrial taxa in flowing streams across all four sites. Formicidae were found during all collection days at each site. Aquatic species were present at all study sites the first day streams began flowing (Table 2). The first day the stream began to flow, the average Shannon Diversity for aquatic invertebrates was 1.06 with a standard deviation of 0.37 (Fig. 3).

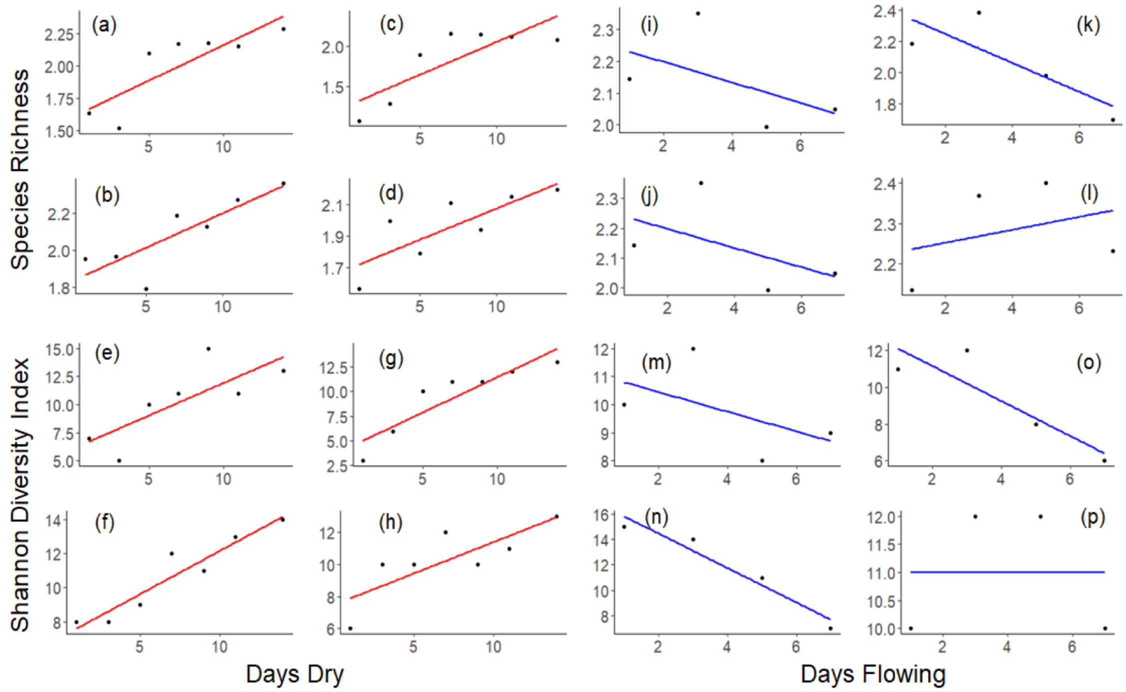

FIG. 2. Linear regression of Species Richness and Shannon Diversity through time during the dry (a-h) and flowing (i-p) phase for all four sites (a) Site 1 ($F_{2,5}$=7.82, r^2=0.61, $p<0.05$). The line of best fit is: 6.12 + 0.58D where D is Days Dry (b) Site 2 ($F_{1,5}$=46.9, r^2=0.90, $p<0.001$). The line of best fit is: 7.1 + 0.51D. (c) Site 3 ($F_{1,5}$=23.9, r^2=0.83, $p<0.05$). The line of best fit is: 4.3 + 0.72 D. (d) Site 4 ($F_{1,5}$=9.12, r^2=0.65, $p<0.05$). The line of best fit is: 7.5 + 0.39D. (e) Site 1 ($F_{1,5}$=11.73, r^2=0.70, $p<0.05$). The line of best fit is: 1.61 + 0.05D where D is Days Dry. (f) Site 2 ($F_{1,5}$ = 12.3, r^2=0.71, $p<0.05$). The line of best fit is: 1.83 + 0.04D. (g) Site 3 ($F_{1,5}$=10.12, r^2=0.67, $p<0.05$). The line of best fit is: 1.24 + 0.08.1D. (h) Site 4 ($F_{1,5}$=9.34, r^2=0.65, $p<0.05$). The line of best fit is: 1.68 + 0.04D. (i-p) $p>0.05$ for all linear fits for each site. Shannon Diversity and richness decreased non-significantly at Sites 1-3.

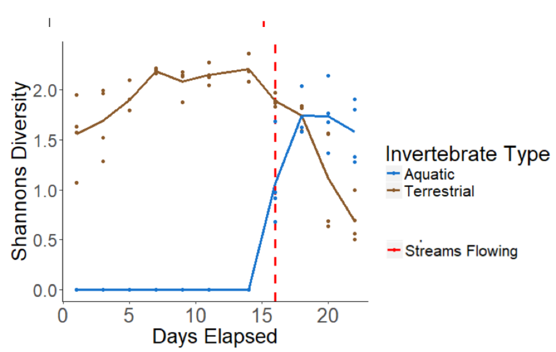

FIG. 3. Average Shannon Diversity of aquatic and terrestrial invertebrates plotted across the Days Elapsed.

TABLE 2. List of aquatic invertebrate taxa found at each stream site on first day surface flows began.

Site	Taxa
1	Naididae
2	Naididae, Simuliidae, Tipulidae Ceratopogonidae, *Caridina weberi*
3	Naididae, Simuliidae
4	Naididae, *Thiara granifera*

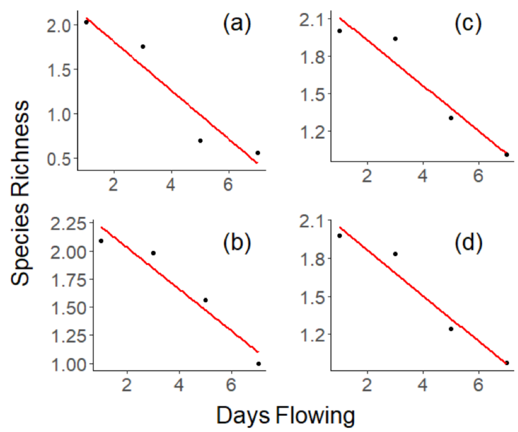

FIG. 4. Linear regression of Shannon's Diversity of terrestrial invertebrates through time during the flowing phase for all four sites. (a) Site 1 ($F_{1,2}$=19.29., r^2=0.91, p<0.05). The line of best fit is: 2.3 – 0.27D where D is Days Flowing. (b) Site 2 ($F_{1,2}$=25.7, r^2=0.93, p<0.05). The line of best fit is: 2.4 – 0.19D. (c) Site 3 ($F_{1,2}$=23.7, r^2=0.92, p<0.05). The line of best fit is: 2.3 – 0.18 D. (d) Site 4 ($F_{1,2}$=37.7, r^2=0.95, p<0.05). The line of best fit is: 2.2 – 0.18D.

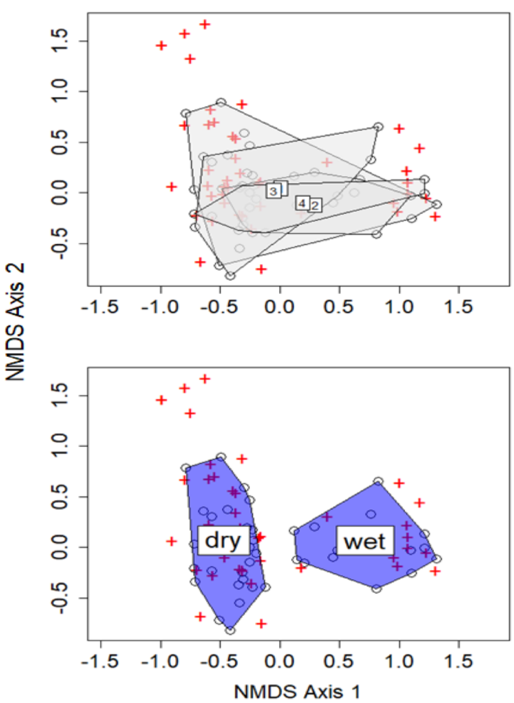

FIG. 5. Non-metric multidimensional scaling plot of temporary stream communities based on species abundance data. Stress = 0.18. (a) Grouped by stream site. (b) Grouped by flow phase (dry and wet).

TABLE 3. A post hoc pair-wise comparison of the four stream study sites. Significant differences between sites are bolded. All p-values were not significant (p>0.05) after Bonferroni adjusted.

Pair	F-Statistic	r^2	p-value
1 vs 2	2.35	0.105	**>0.05**
1 vs 3	2.61	0.115	**>0.05**
1 vs 4	2.17	9.81×10^{-2}	**>0.05**
2 vs 3	1.53	7.11×10^{-2}	<0.05
2 vs 4	0.91	4.35×10^{-2}	<0.05
3 vs 4	1.31	6.16×10^{-2}	<0.05

Annelida in the family Naididae were present at all four sites the first day the stream was flowing (Table 2). *Caridina weberi* were present at all sites within 3 days after streams began to flow and families Gerridae and Saldidae were present within five days. Aquatic and terrestrial invertebrates sampled were affected differently as the days elapsed since the stream started flowing. The diversity of aquatic invertebrates showed a non-significant increase at Sites 1, 3, and 4, and a non-significant decrease at Site 2 (p>0.05 for all linear fits for each site). Terrestrial invertebrate diversity significantly decreased across all sites as the stream continued to flow (Fig. 4)

Invertebrate communities were significantly different across each site (PERMANOVA, F_3=1.85, p<0.05) (Fig. 5a). Before Bonferroni correction, Site 1 was significantly different when compared to Sites significantly different when compared to Sites 2, 3, and 4. Sites 2, 3, when compared to Sites 2, 3, and 4. Sites 2, 3, and 4 were not significantly different from each other (Table 3). Invertebrate community assemblages found in dry streams were significantly different from those found in streams that were flowing (PERMANOVA, F_1=16.1, p=0.001) (Fig. 5b).

Rehydration experiment

No eggs, larvae, or aestivating aquatic invertebrates were found from the soil divots examined initially without rehydration. Three individuals from the subclass Acari were present in the initial soil sample from Site 2. No invertebrate emergence was observed from rehydrated soils throughout the five-week experiment.

Discussion

Temporary streams are characterized by distinct shifts from aquatic to terrestrial habitats and vice versa, and indeed the invertebrate fauna that inhabit temporary streams are significantly different when the stream is dry compared to when the stream is flowing (Fig. 5b). Few ecosystems support two distinct communities in the same spatial boundaries due to cyclic temporal changes. There was a marked difference between the invertebrate assemblages found at Site 1 and those found at Sites 2, 3, and 4. This is most likely due to the stark difference in elevation levels between the sites—Site 1 was at sea-level, while Sites 2, 3, and 4 were 230 meters above sea-level.

The present study supports the findings of Sánchez-Montoya et al. (2016a), in that the diversity of terrestrial invertebrates increases over time in dry channels. This recolonization of dry stream beds by terrestrial invertebrates is crucial for important ecological processes including pollination, seed dispersal, soil aeration, as well as nutrient breakdown and recycling (Taylor and Doran 2001). Dry streambeds are harsh environments lacking vegetation and thus are exposed to solar radiation and wind (Steward et al. 2011). However, favorable biotic conditions including fewer competitors for resources and abundant food sources including dead aquatic organisms and algae, account for the immediate and continued colonization by terrestrial invertebrates in the dry channels investigated (Paetzold et al. 2005; Sánchez-Montoya et al. 2016a). Several orders of Insecta found in the present study are capable of flight including Orthoptera, Psocoptera, Hemiptera, Coleoptera, and Diptera (Appendix A). As these organisms were not found in flowing streams, this suggests that most flying invertebrates are able to escape the onset of water flow.

In a study of Australian and Italian temporary streams, Steward et al. (2011) found that the invertebrate community that colonized dry streambeds is a unique assemblage in comparison to the adjacent riparian community. Building upon my study, a future study on Moorea should sample terrestrial invertebrates in adjacent riparian zones to determine if dry streambeds support unique taxa. Furthermore, two skink species, *Emoia cyanura* and *Emoia impar* were observed at all stream sites beginning five days after surface flows had ceased. Dry streambeds are similarly important to terrestrial vertebrates acting as biological corridors that connect habitats and maintain biodiversity and key ecological processes (Sánchez-Montoya et al. 2016b)

While the two communities sampled in dry channels and flowing streams were distinct, the fauna sampled during flowing streambeds was a unique mixture of aquatic and terrestrial invertebrates. None of the terrestrial invertebrates found in flowing streams were capable of flight. Many of these invertebrates, however, are able to survive submersion in water. Species of Chilopoda, Diplopoda, and terrestrial Oniscidea are able to survive several days to week's underwater—certain millipede species are able to survive submersion for over two months (Tufová and Tuf 2005). Amphipods in the family Talitridae, such as *Talorchestia rectimana* which was prevalent in flowing streams, have been shown to have varying levels of submersion-resistance (Spicer and Taylor 1986). It has also been noted during flood events that Formicidae colonies group together at the surface of the water with mated queen ants (Morril 1974). Flooding of temporary streams on Moorea may play an essential role in the dispersal of many inundation-tolerant terrestrial invertebrates.

Flooding events that wash terrestrial invertebrates into streams could also be a key source of nutrients in downstream catchments. Formicidae, which were present in all flowing temporary streams, are a major source of food for fish on Moorea, including *Kuhlia marginata* (Resh et al. 1999). 70% of *K. marginata* sampled had Formicidae in their stomachs (Resh et al. 1999). Another Moorean fish, *Eleotris fusca,* was also found to eat terrestrial invertebrates including Formicidae, Coleoptera, Isopoda, and Diplopoda (Resh et al. 1999).

The aquatic invertebrate assemblages inhabiting temporary streams are less diverse in comparison to perennial streams on Moorea. Although similar sampling methods were used, the present study found 23 different taxa across 4 study temporary sites, whereas Resh et al (1990) found 48 taxa across 8 perennial sites, and Groff (2006) found 52 taxa across 15 perennial sites. Furthermore 14 of the 23 taxa in flowing temporary streams were terrestrial invertebrates, Resh et al. (1990) and Groff (2006) found predominantly aquatic invertebrates. As data was only collected from flowing streams for 1 week before they stopped flowing, future studies should monitor temporary streams during the wet season when they flow for longer periods of time.

Aquatic invertebrates colonized the newly flowing streams the same day they began to flow. Aquatic invertebrates most likely colonized the flowing streams by drifting downstream from a perennial source. For example, there was a perennial stream that was flowing into the ground a few hundred meters upstream of Site 2. Due to the speed at which aquatic invertebrates colonized flowing streams, perhaps all study sties were temporary reaches that connected to permanent streams and were activated when precipitation raised ground-water levels. Other dispersal methods such as travelling via animal vectors (inside bird feces), wind-mediated dispersal on bryophytes, and oviposition by aerial insect may have also aided the colonization of temporary streams by aquatic invertebrates (Bilton et al. 2001; Green and Sánchez 2006; Bitušík et al. 2017).

The lack of success of my rehydration experiment suggests that aestivating invertebrates play little role in colonizing temporary streams when they resume flow. As entering dormancy requires the evolution of specialized stages with reduced metabolic rates and resistance to desiccation, it is possible that few species on Moorea enter dormancy while other forms of dispersal predominate. Many factors may have negatively influenced my rehydration experiment. Dormant organisms may have been present in deeper or shallower soil in relation to my samples. Five weeks of rehydration may not have been long enough to see any invertebrate emergence. Although water used for rehydration was changed every other day, it may have become hypoxic and killed any organisms living in the soil. Additionally, the rehydration experiment was conducted near the end of Moorea's dry season which would require dormant organisms to persist within soil for several months. A similar rehydration experiment should be conducted at the end of the wet season in Moorea using flowing freshwater aquaria. At this time, temporary streams will have just stopped flowing after prolonged periods of flow, and there may be a higher probability of finding dormant aquatic organisms within soil.

Conclusion

Diverse aquatic and terrestrial invertebrate communities inhabit temporary streams on Moorea, French Polynesia. Temporary streams should not be considered terrestrial habitats that are periodically flooded, nor aquatic habitats that intermittently dry, but rather a dynamic mixture of both ecosystems. Invertebrate inhabiting temporary streams influence adjacent terrestrial habitats, and downstream catchments, playing roles in many ecological processes. Climate change models have predicated more variable precipitation and temperature in the future which will increase the frequency of flooding and drying events (Lake et al. 2000). Such changes may drastically alter the natural colonization patterns of the invertebrates that inhabit temporary streams. The present study acts as an initial survey, providing a baseline for future invertebrate community assemblage studies in temporary streams.

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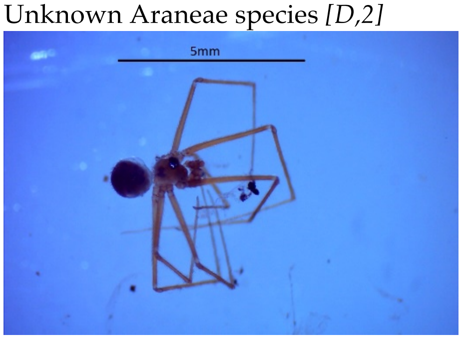
APPENDIX A

B=Found in both dry and flowing streams, F=Found in flowing streams, D=Found in dry streams
1=Found at Site 1, 2=Found at Site 2, 3=Found at Site 3, 4=Found at Site 4

TERRESTRIAL INVERTERBRATES

ARTHROPODA
Arachnida
Acari *[B,1,2,3,4]*

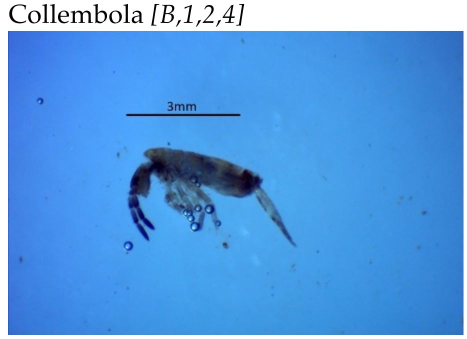
Order Araneae
Unknown Araneae species *[D,2]*



Cyrtophora moluccensis (Doleschall, 1857)
[D,2,3,4]

Chilopoda
Family Cryptopidae
Cryptops niuensis (Chamberlin, 1920)
[B,1,2,3,4]

Collembola *[B,1,2,4]*



Crustacea
Order: Isopoda
Unknown Oniscidea species
[B,1,2,3,4]

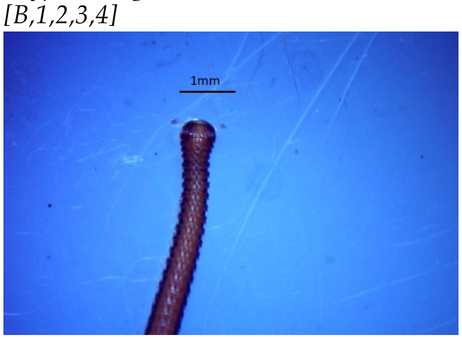
Cubaris murina (Brandt 1833)
[B,1,2,3,4]

Order Amphipoda

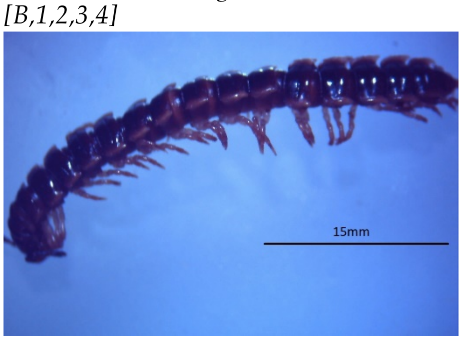
Talorchestia Rectimana (Dana, 1852)
[B,2,3,4]

Diplopoda

Family Cambalopsidae:
Glyphiulus granulatus (Gervais, 1847)
[B,1,2,3,4]



Family Paradoxosomatidae:
Oxidus gracilis (Koch, 1847)
[B,1,2,3,4]



Family Trigoniulidae:
Leptogoniulus sorornus (Butler, 1876)
[B,1,2,3,4]

Insecta

Order Diptera

Family Choloropidae
[D,1,2,3]

Family Drosophilidae
[D,1,2,3,4]

Family Sarcophagidae
[D,1]

Order Coleoptera
Family: Curculionidae

Unknown Curculionidae species
[B,1,2,3,4]

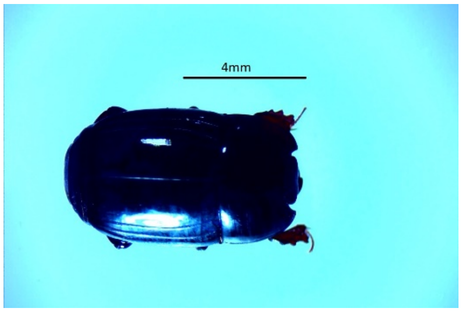
Genus *Xyleborus*
[D,1,2,3,4]

Family: Nitidulidae
Unknown Nitidulidae species
[D,2]

Stelidota nigovaria (Fairmaire, 1849)
[D,1,2]

Epuraea ocularis (Fairmaire, 1849)
[D,1,2,3]

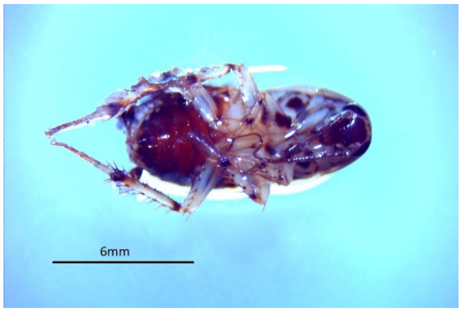
Family: Histeridae
[D,4]



Order Lepidoptera
Family Geometridae
[D1]

Order Hymenoptera
Family: Formicidae
[B,1,2,3,4]

Order Blattodea
Unknown Blattodea species
[D,1]



Order Hemiptera
Unknown Hemiptera species
[D,1]

Family Lygaeidae
[D,1]

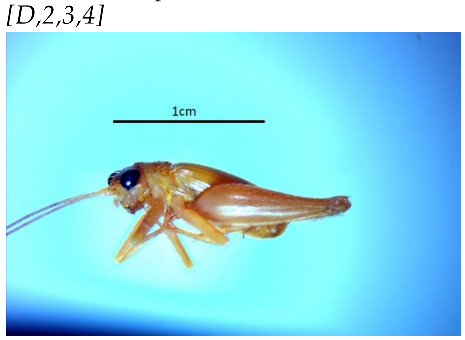
Family: Issidae
[D,1]

Family: Cicadellidae
[D,1]

Order Psocoptera
[D,1,2,3]

Order Dermaptera
Family Labiinae
[B,3]

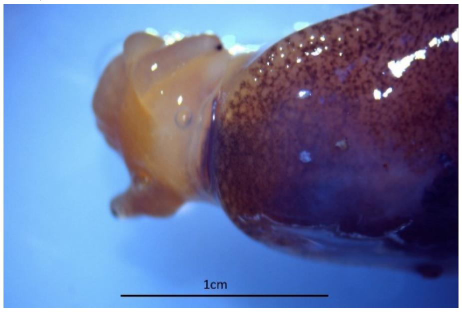
Order Orthoptera
[D,2,3,4]



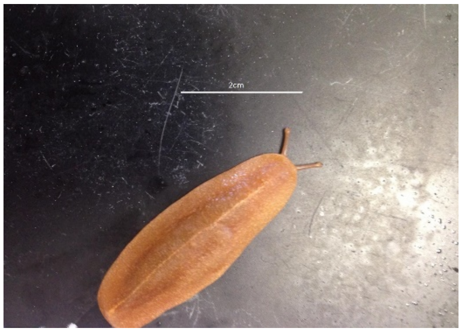
MOLLUSCA

Family Veronicellidae

Vaginulus plebeius (Fischer, 1868)
[D,4]

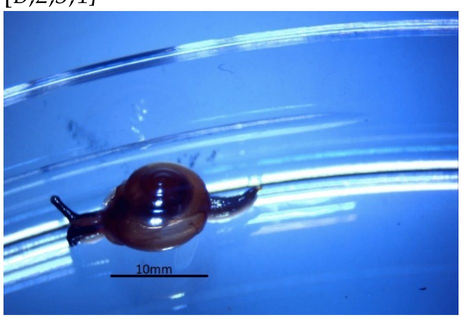


Laevicaulis alte (Férussac, 1822)
[B1,4]



Family: Helicarionidae

Ovachlamys fulgens (Gude, 1990)
[*B,2,3,4]*

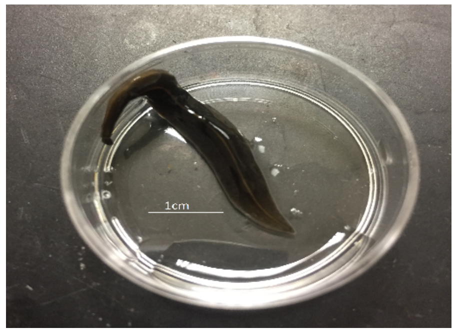


PLATYHELMINTHS

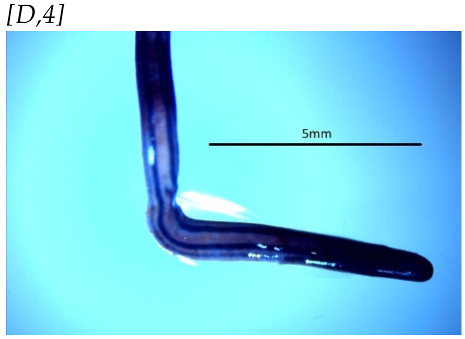
Order: Tricladida

Unknown Tricladida species *[D,3]*

Platydemus Manokwari (De Beauchamp, 1963)
[D,3,4]



Order Seriata
[D,4]



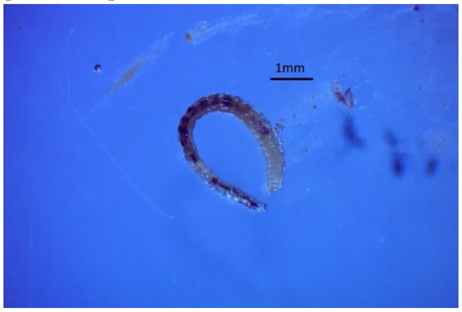
AQUATIC INVERTERBRATES

ANNELIDA

Oligochaeta

Family: Naididae

[F,1,2,3,4]



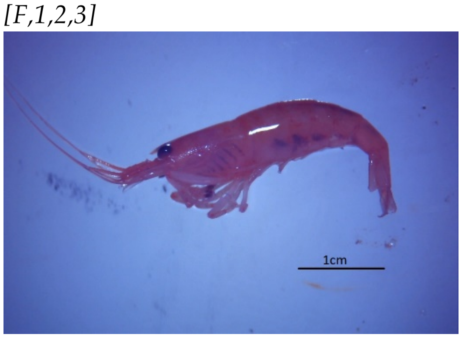
ARTHROPODA

Crustacea

Family: Atyidae

Caridina weberi (De Man, 1892)

[F,1,2,3]



Insecta

Order Diptera

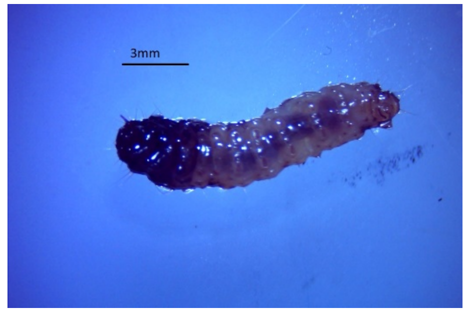
Family: Simuliidae

Simulium species (Latreille, 1802)

[F,1,2,3,4]

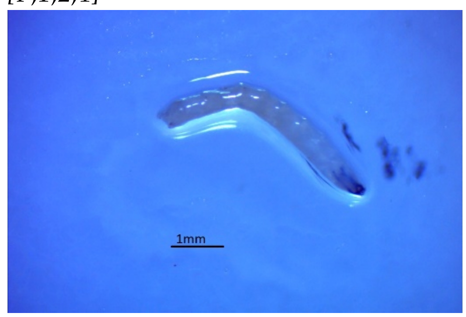
Family: Tipulidae

[F,1,2,3]



Family: Ceratopogonidae

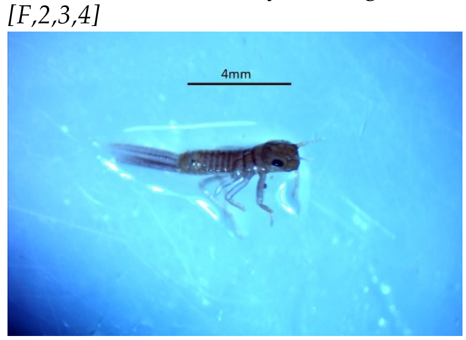
[F,1,2,4]



Order Odonata

Family Coenagrionidae

[F,2,3,4]

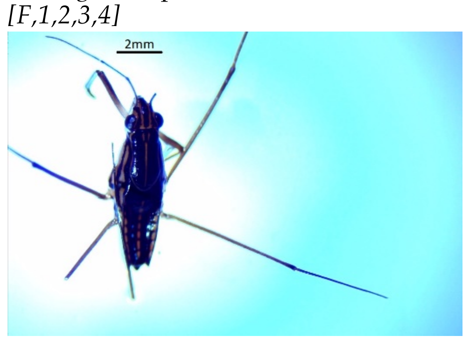


Order Hemiptera

Family Gerridae:

Limnogonus species (Stål 1868)

[F,1,2,3,4]



Family Saldidae

Saldula species

[F,1,2,3,4]

MOLLUSCA

Family Thiaridae

Thiara granifera (Lammarck 1816)

[F,1,2,4]