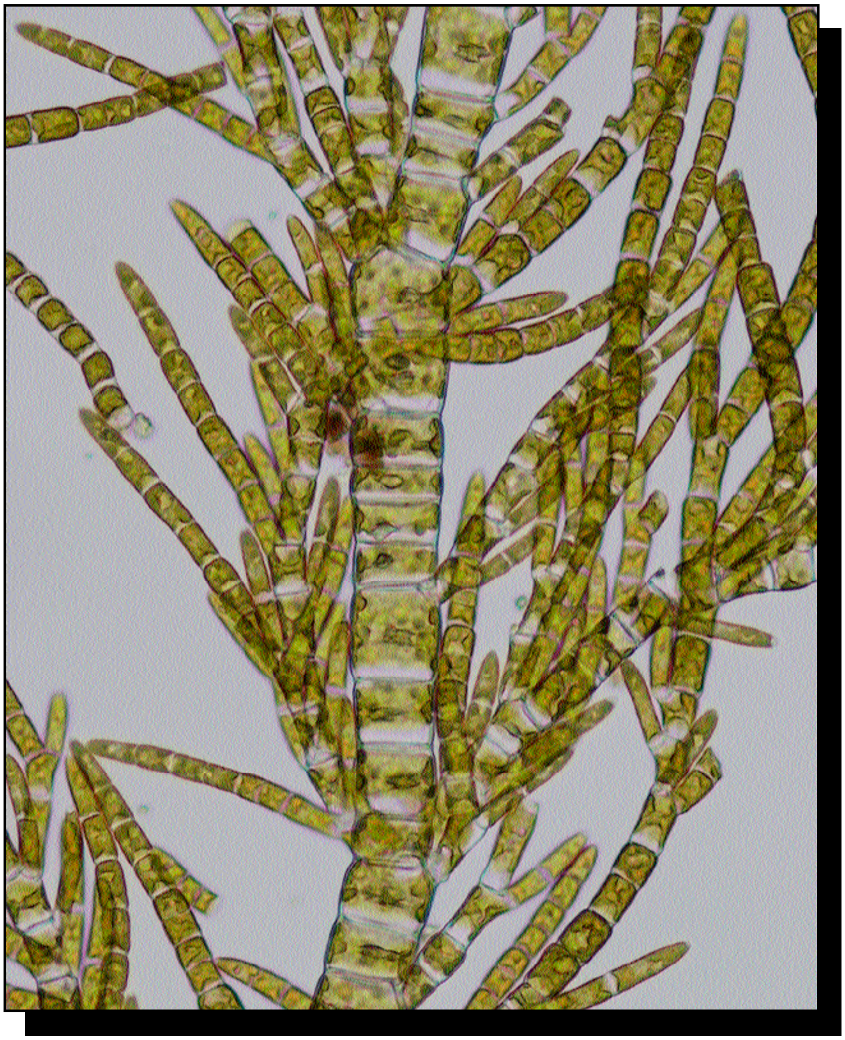

Department of Land and
Natural Resources

Division of
Aquatic Resources

Technical Report
04-01

Seasonality of Algae in Waiāhole and Kahana Streams, Windward O‘ahu, Hawai‘i

May 2004

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Photos by Alison Sherwood

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DAR Technical Report 04-01

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Introduction

The seasonality of algal communities in stream systems has been well studied in mainland North America as well as on other continents (e.g. Pfister 1993, Rout & Gaur 1994, Biggs 1995, Leukart 1995, Sherwood & Sheath 1999, Sherwood *et al.* 2000), and community variations in these systems have been demonstrated to be driven by such factors as water temperature, day length and flood regime. Seasonal variations in temperate streams are related to multiple factors, such as irradiance, nutrient concentrations, water temperature, and storm events (Rosemond 1994). A study of an Arizona desert stream demonstrated that algal assemblages dominated by diatoms are more resistant to scouring by flash floods than macroalgal assemblages (Grimm & Fisher 1989); however, the resilience to these events is dependent on the level of biotic production in the stream. In contrast to mainland systems such as this, algal seasonality in Hawaiian streams has not been adequately investigated. Except for a single study that examined the periphyton communities of Hawaiian streams over a 6-week period (LaPerriere 1995), and a preliminary report on the effects of flow regime on stream productivity (Chong 1996), no published works exist for Hawaiian stream systems that investigate algal community changes over a period of time.

It is possible that the most influential factors driving algal community changes differ between mainland and Hawaiian streams, since the important temperate factors of air temperature and day length are much less pronounced in annual variation in Hawaiʻi. For example, the flashy nature of Hawaiian streams (Fitzsimons and Nishimoto 1997) means that flood events may be a stronger factor in determining algal community structure than variations resulting from changing seasons. In order to examine correlations between the algal and fish communities, the natural variation in these communities must be understood. In contrast to the algal community, a strong emphasis has been placed on monitoring of the native fish populations in Hawaiian streams in recent years (e.g. HDAR and USGS surveys). The current study was designed and conducted in an effort to begin to address this imbalance in stream monitoring activities. Two windward Oʻahu streams were monitored bi-monthly for 13 months in order to examine the relationships between changes in algal community composition and physical and chemical stream characteristics. The present report provides the most comprehensive examination of stream algae seasonality in Hawaiʻi to date.

Materials and Methods

Field methods

Two transects were established (one each on Waiāhole and Kahana Stream) on the island of Oʻahu, and were examined twice monthly from November 2002 until November 2003. The Waiāhole Stream transect was situated (for ease of accessibility) approximately 50 m upstream from Kamehameha Highway, close to the Waiāhole Poi Factory (21°28.957 N, 157°50.740 W). The Kahana Stream transect was placed at the front side of the dam at the Nākoa Trail crossing of the stream, but away from the area where hikers would impact the algal community (21°32.449 N, 157°52.922 W). This site was chosen since earlier surveys of the macroalgae in Kahana Stream revealed that this area had a very high algal diversity (Sherwood 2002a,b). Each transect was established using fixed marker points on either side of the stream to ensure that the transect points were located in the same position for each sampling period. In both Waiāhole and Kahana Streams, a measured line was stretched across the stream, which had a 5-m transect marked in 20-cm intervals (Fig. 1).

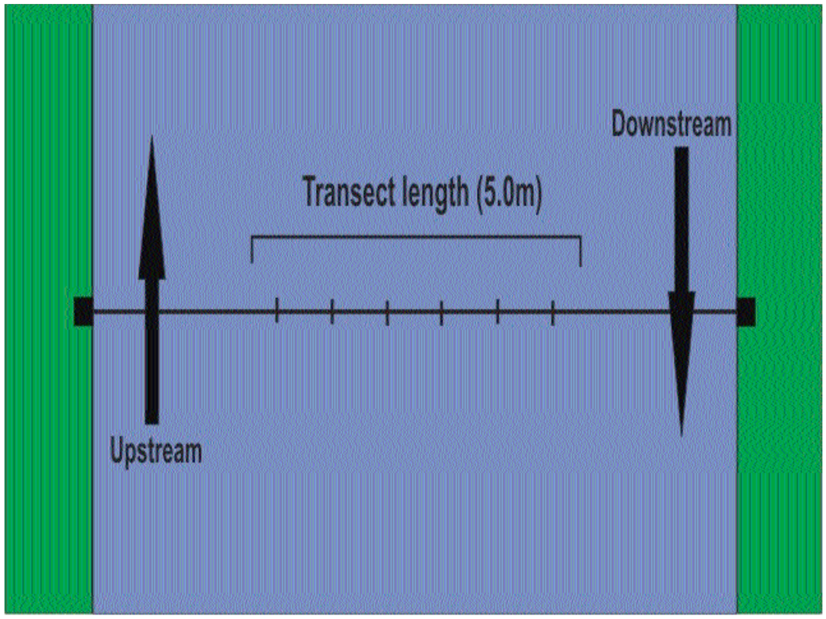

Fig. 1. Schematic of the transect for Waiāhole and Kahana Streams. In both cases a line was established across the stream channel and a 5-m line was sampled twice monthly.

Each transect was monitored twice monthly for several physical and chemical stream characteristics, as well as changes in algal community composition. Water temperature, specific conductance, pH, and water condition (clear or turbid) were measured or noted at a single location for each stream (the same location each sampling period). Water depth was measured at each 20-cm interval across the 5-m transect using a Lufkin folding rule (to the nearest 0.5 cm), and measurements were verbally recorded using an Olympus S713 Microcassette Recorder. Current velocity was also measured at each 20-cm interval using a GlobalWater FlowProbe flow meter. Velocities were recorded (also using a Microcassette Recorder) as the mean velocity over a 10-second time period. Using a glass-bottomed viewbox, the composition of the algal community at each 20-cm interval was noted for an area the size of a standard petri dish. Representative samples of each alga were taken, when needed, and fixed in 2.5% $CaCO_3$-buffered glutaraldehyde for laboratory identification. The transect in Waiāhole Stream was positioned in a natural region of the stream, and so substrate size and composition were also noted for each 20-cm interval across this stream. In contrast, the Kahana Stream transect was located in a high diversity area at the leading edge of a cement dam, and so substrate size and composition were not considered for this stream site. Stream discharge data from USGS gauges on Waiāhole and Kahana Streams were downloaded (as "recent data") from the USGS water data website (*http://waterdata.usgs.gov /hi/nwis/sw*) for the time interval of the study (November 2002 - November 2003); however, data for Waiāhole Stream were only available for the period of November 2002 - June 2003.

Laboratory Methods and Data Analyses

Macroalgae were identified using an Olympus BX-41 compound microscope and were photographed with an Olympus DP12 digital camera system. Literature references for identification are given in previous reports (Sherwood 2002a, 2002b). Depth and current velocity profiles were generated for each stream segment and each sampling date, and substrate size and composition for Waiāhole Stream were also graphically visualized in order to observe trends over time. The physical and chemical parameters measured (pH, water temperature and specific conductance) were graphed so as to be displayed over time. Daylength data were obtained from the Hawai‘i Institute for Astronomy website (*http://www.ifa.hawaii.edu/*), and were also graphed. Data were compared across sites and over time through visual comparisons of the graphs. The Spearman Rank Measure of Correlation was employed to examine associations among temperature, specific conductance, average depth, current velocity and daylength. Data were ranked and analyzed using the Minitab statistical package (Ryan *et al.* 1985).

Results and Discussion

Physical and Chemical Stream Characteristics

The pH values remained relatively steady for both Kahana Stream (7.7-7.8) and Waiāhole Stream (7.8-8.0) over the course of the study (Fig. 2). Water temperatures fluctuated more throughout the sampling period (between 19.5-24.0°C), decreasing slightly in the winter months (Fig. 2). Specific conductance values were quite steady for both streams (which were also very similar to each other in value; between 70-90 µS/cm), except for a sharp decrease in one of the spring samplings of Waiāhole Stream, which corresponded to a period of high rain and flooding in the stream (Fig. 2). Hours of daylight varied according the season, and ranged between 10 hours 51 minutes and 13 hours 25 minutes (Fig. 2).

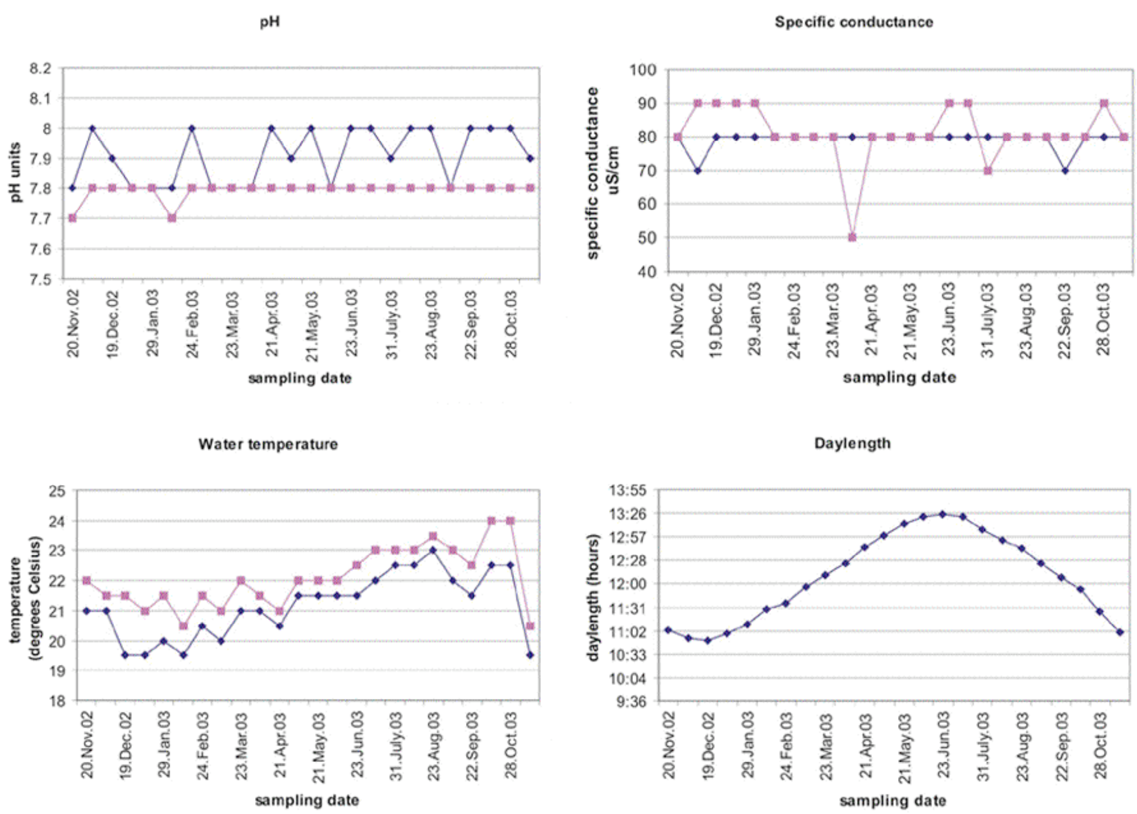

Fig. 2. pH, temperature, specific conductance and daylength values for each sampling date. The dark blue line indicates data from Kahana Stream, while the pink line indicates data from Waiāhole Stream. Daylength data were obtained for a station at Lanikai via the Hawai‘i Institute for Astronomy.

Trends in stream depth for Waiāhole Stream

Depths of the Waiāhole Stream transect were relatively constant for the first four samplings (20.November.2002 – 14.January.2003) (Fig. 3). The 29.January.2003 and 04.April.2003 samplings, however, were much higher than for the other sampling periods. The sharp decrease at meter 5.6 during all four sampling periods on the first graph was a result of a large rock that was subsequently moved during the January/early February flood and high water events. A decrease in water depth was seen in the sampling periods from the end of May 2003 until early September 2003, with a region of zero depth from meter 3.8 to meter 5.2. This was the result of a major shift in stream bed morphology at this time, such that the middle portion of the transect became an exposed island of zero depth. The causal factors for this change are unknown, but other evidence of stream bed changes was also visible downstream of the transect (close to the bridge crossing Kamehameha Highway). Water depths at the left and right ends of the transect also decreased slightly from previous months of sampling, possibly due to lowered water renewal in the drier months in Hawai'i (summer). By the late September 2003 sampling period, however, another

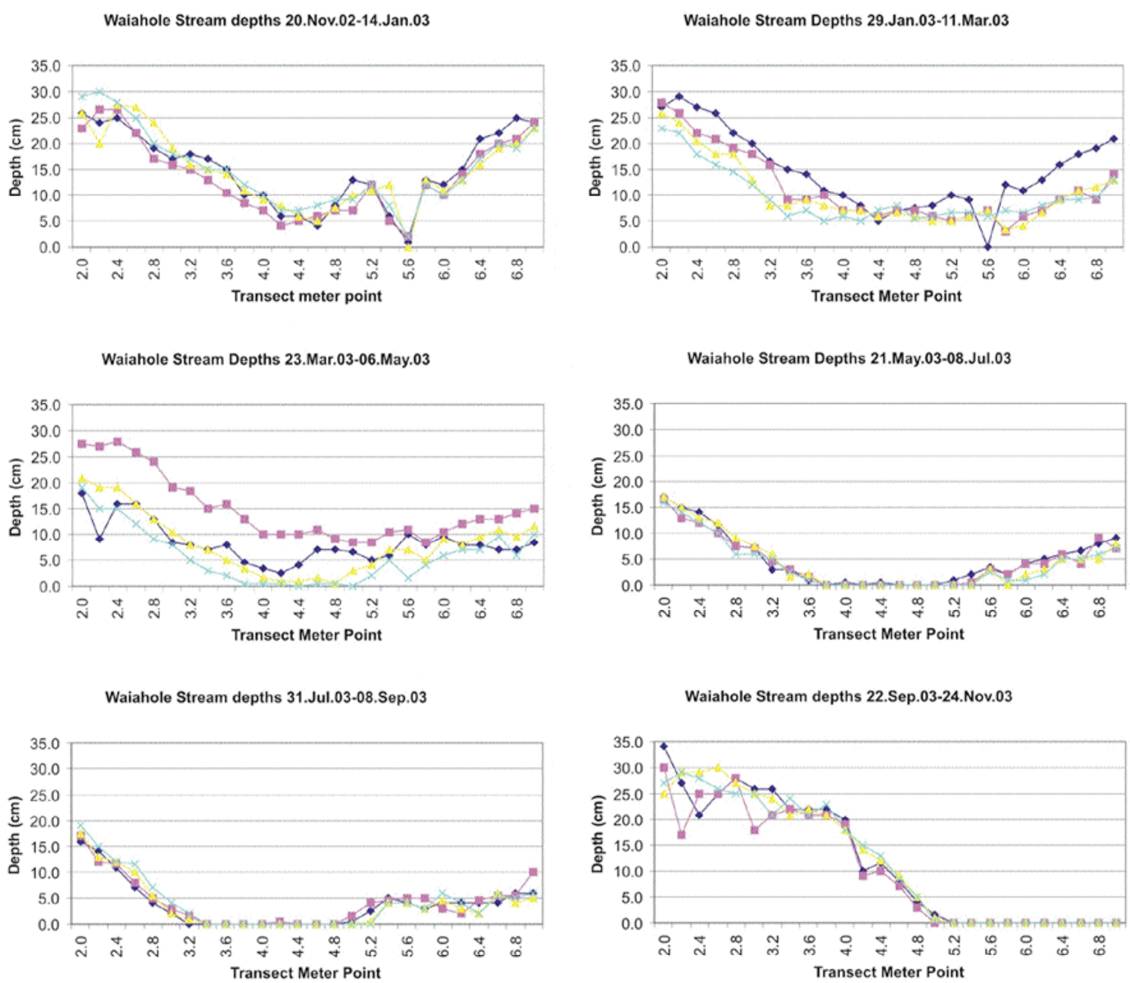

Fig. 3. Changes in water depth across the Waiāhole Stream transect, for each sampling date. Each graph represents four sampling dates. The dark blue line indicates data from the first sampling date, the pink line for the second date, the yellow line for the third date, and the light blue line for the fourth date.

shift in stream bed morphology had occurred, resulting in a markedly different depth profile for the transect (Fig. 3). The exposed area of the transect was relocated to the far end (meter 5.2-7.0), and water depths for the opposite end of the transect were much higher than in previous sampling periods (up to ca. 35 cm).

Trends in current velocity for Waiāhole Stream

Current velocity readings across the Waiāhole Stream transect were extremely variable over time (Fig. 4). In general, however, the peaks and valleys of current velocity corresponded well with times of high and low water depth, respectively. For example, the lowered current velocity readings near the middle of 2003(from the end of April until June) also corresponded to the times of lowest stream depth (Fig. 3). Current velocities generally decreased from winter 2003 until summer 2003, as the seasons changed from the wet months to the drier months in Hawai‘i. Greater variability in current velocity than water depth was seen across the transect on any one sampling date, due to the presence of pools and eddies in

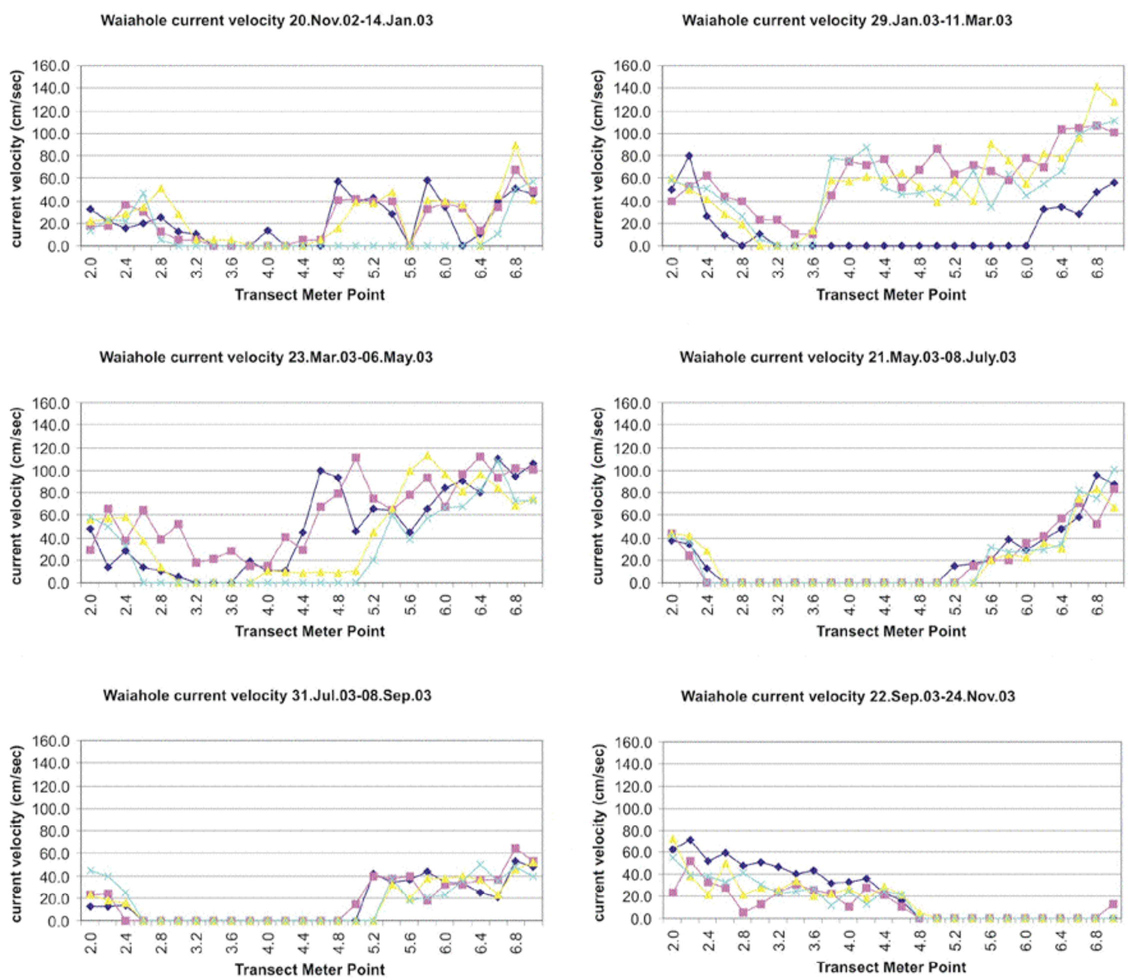

Fig. 4. Changes in current velocity across the Waiāhole Stream transect, for each sampling date. Each graph represents four sampling dates. The dark blue line indicates data from the first sampling date, the pink line for the second date, the yellow line for the third date, and the light blue line for the fourth date.

the stream that decreased the current velocity while not affecting the depth as much. The changes in stream bed morphology in early May and late September 2003 strongly impacted the flow regime in the transect, as evidenced by the high numbers of zero flow readings during the last half of the study (Fig. 4).

Trends in water depth for Kahana Stream

The profile of the Kahana Stream transect was characterized by a slow increase in depth from left to right, followed by a very sharp increase in depth, which then gradually decreased to zero depth (Fig. 5). This sharp increase was due to a physical drop-off along the cement dam. As for Waiāhole Stream, the first four sampling dates yielded very similar depth recordings, and the 04.April.2003 recordings were much higher than other sampling periods due to flooding conditions. In contrast to the results for Waiāhole Stream, however, the 29.January.2003 sampling did not have elevated depth recordings with respect to other sampling periods. Following the 21.April.2003 sampling the water depths were observed to decrease overall, and this lowered water level was present up until the last samples were taken

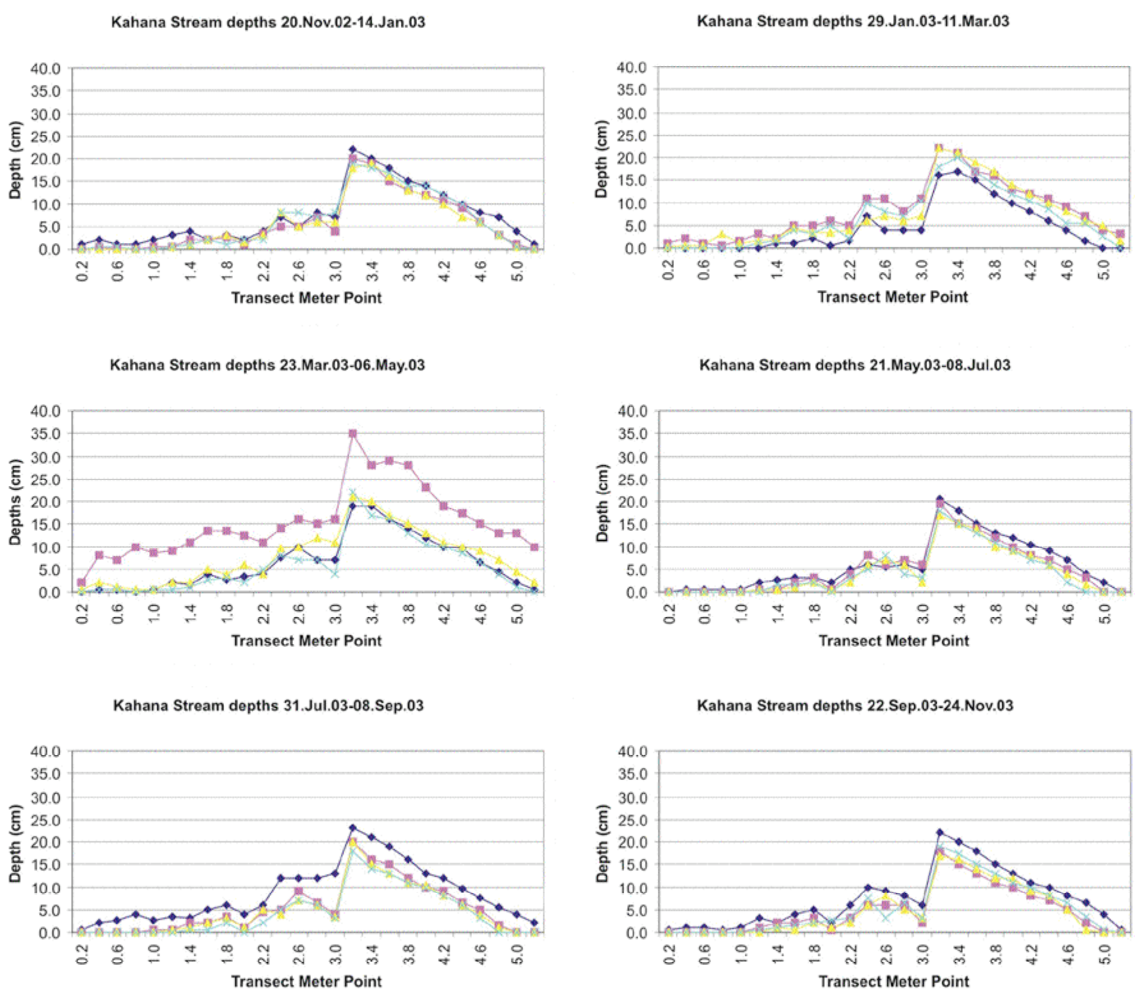

Fig. 5. Changes in water depth across the Kahana Stream transect, for each sampling date. Each graph represents four sampling dates. The dark blue line indicates data from the first sampling date, the pink line for the second date, the yellow line for the third date, and the light blue line for the fourth date.

(November 2003). Although greater fluctuations in water depth were evident in the winter months, most likely due to periodic flooding events, the overall water level did not decrease with the start of the summer months and the drier season. The larger fluctuations observed for Waiāhole Stream may be more attributable to the shifts in stream bed morphology in that stream, rather than seasonal changes in recharge.

Trends in current velocity for Kahana Stream

The peak date of stream depth (Fig. 5) for Kahana Stream (04.April.2003) also corresponded to the peak date of current velocity (Fig. 6). As was observed for the stream depths, and contrary to the results for Waiāhole Stream, current velocity did not decrease overall as the collection times shifted from the wetter, winter months to the drier, summer months. Current velocity recordings for the Kahana Stream transect were similar to one another for the first four sampling periods, but much more variation was observed in the second and third set of measurements. The large range of current velocities seen across

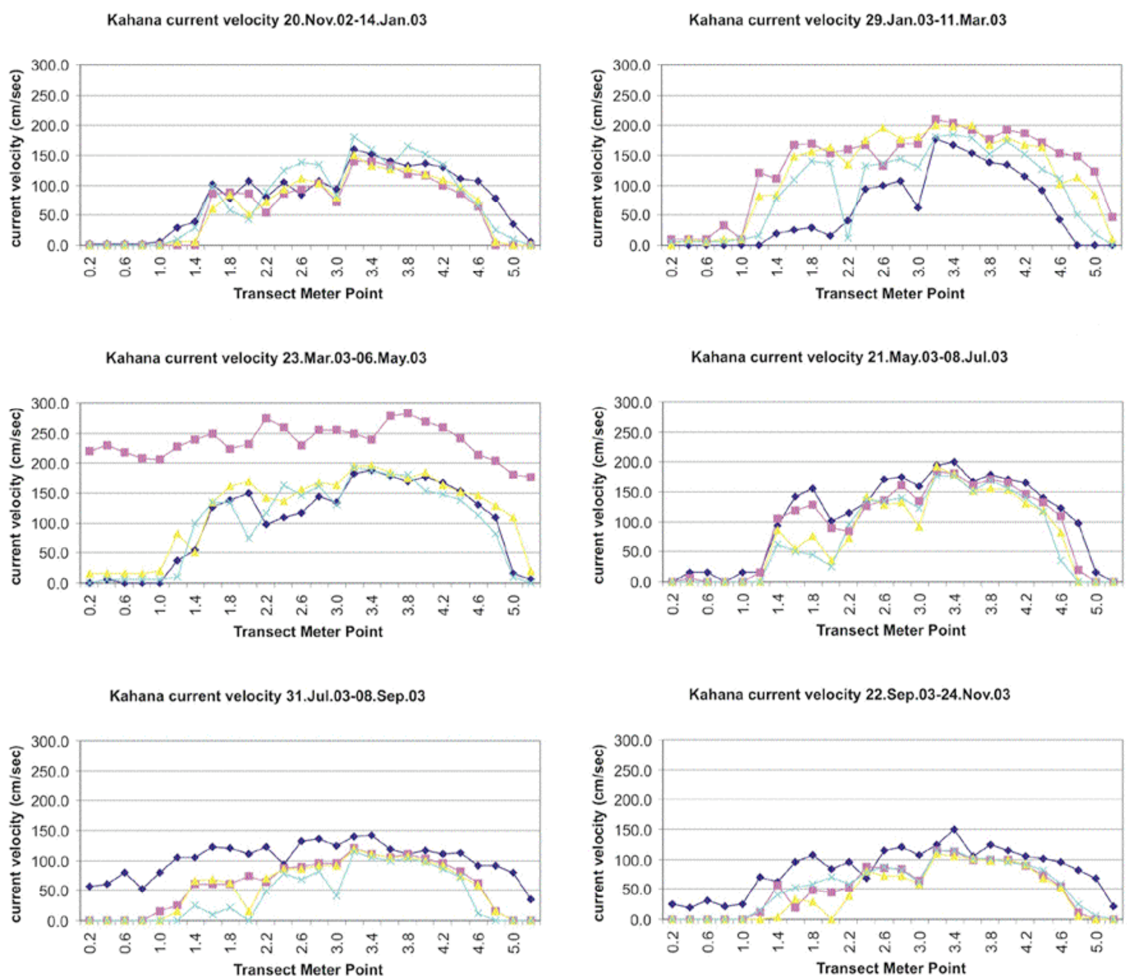

Fig. 6. Changes in current velocity across the Kahana Stream transect, for each sampling date. Each graph represents four sampling dates. The dark blue line indicates data from the first sampling date, the pink line for the second date, the yellow line for the third date, and the light blue line for the fourth date.

the transect for Waiāhole Stream is not evident for the Kahana Stream transect, likely because the latter site is positioned on a cement dam with relatively steady unidirectional water flow, and the subsequent lack of pools and eddies in the transect has resulted in more uniform current velocities across the transect for any one sampling date.

Comparison of Mean Discharge for Waiāhole and Kahana Streams

Comparison of mean discharge for Waiāhole and Kahana Streams over the study period (November 2002 – November 2003) illustrates that the fluctuations in discharge were much higher in the latter than the former (Fig. 7). Ten days were reported to have a mean discharge greater than 100 cubic feet per second for Kahana Stream, while mean discharge for Waiāhole Stream did not exceed 30 cubic feet per second during the study period. Mean discharge for Waiāhole Stream generally decreased over the study period, and the sharpest drop (at the end of April 2003) also corresponded to the time of decreased stream depth and current velocity recorded in the transect (Figs. 3, 4). Figs 8-9 illustrate the difference between high and low flow in the transect areas of both Waiāhole and Kahana Streams.

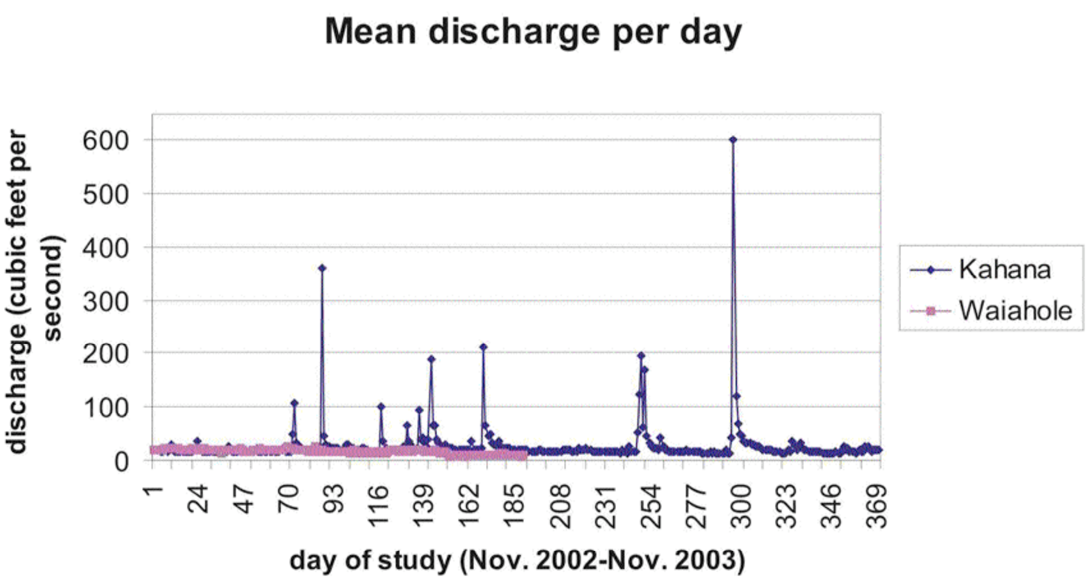

Fig.7. Comparison of mean discharge per day for Waiāhole and Kahana Streams over the length of the current study. Data were obtained from a USGS website (see Materials and Methods for details), at sites close to the sampled transects within each stream. Waiāhole Stream mean discharge data are in blue, while Kahana Stream mean discharge data are in pink.

Trends in Substrate Size and Composition in Waiāhole Stream

Since the Waiāhole Stream transect was placed in a natural area of the stream, it was possible to monitor the changes in substrate composition and size over time. Figure 10 represents a time series of the monitored transect (visualized from the top to the bottom of the figure), with the dominant substrate indicated for each transect point examined. Substantial shifts in the substrate occurred very quickly (e.g. in the span of time between two sampling periods). A gradual accumulation of allochthonous material was seen from 05.December.2002 until 29.January.2003. The flooding event immediately prior to the 18.February.2003 sampling was most likely responsible for the removal of this material and exposure of

Fig. 8. Photographs of the monitored transect area in Waiāhole Stream during normal flow (May 2003), and high flow (December 2003).

sand and rocky areas on the stream bottom. Allochthonous material slowly accumulated again in the transect following this flood (until 05.June.2003), but the regions of greatest accumulation corresponded to those of zero depth and current velocity; i.e. material was accumulating on the exposed "island" that became established in the center of the stream transect toward summer 2003. The shift of this build-up of material in September 2003 is also evident from the illustration, and the exposed area remained on the far right side of the transect for the remainder of the study.

A closer examination of the changes in size of substrate (Fig. 11) reveals even greater changes. With this fine scale of resolution it is even possible, in some cases, to track the movement of individual rocks through the monitored transect. The substrate of Waiāhole Stream moved considerably over the course of several weeks, which was the typical time between sampling periods; this is evident from the observation that no two consecutive sampling periods had the same substrate composition. It is also evident from this time series that the sandy area toward the left of the stream transect was not stationary; rather, it shifted substantially from side to side over the course of time between sampling periods. This sandy area was also seen to expand, especially during August and early September 2003, which corresponded to times of decreased water depth, current velocity and mean discharge. The shift of the exposed area to the left hand side of the transect is also evident.

Fig. 9. Photographs of the monitored transect area in Kahana Stream during normal flow (May 2003), and high flow (December 2003).

Water Condition in Waiāhole and Kahana Streams

The condition of the water in the two streams was generally seen to be clear and colorless, with a few exceptions. Turbid water was recorded for the first two sampling dates for Waiāhole Stream (20.November.02 and 05.December.02) and the peak flow sampling following a major rain event (04.April.03). Likewise, for Kahana Stream, turbid water was recorded for the sampling date immediately following a major storm (04.April.03), as well as an additional date (29.January.03) during the generally wet, winter months.

Trends in Macroalgae Community Composition

Over the sampling period of November 2002 to November 2003, a total of six macroalgae were identified from Waiāhole Stream and seven macroalgae from Kahana Stream (Plate 1, Table 1). Both streams also had large periphyton growths that were included in the survey. The taxonomic composition

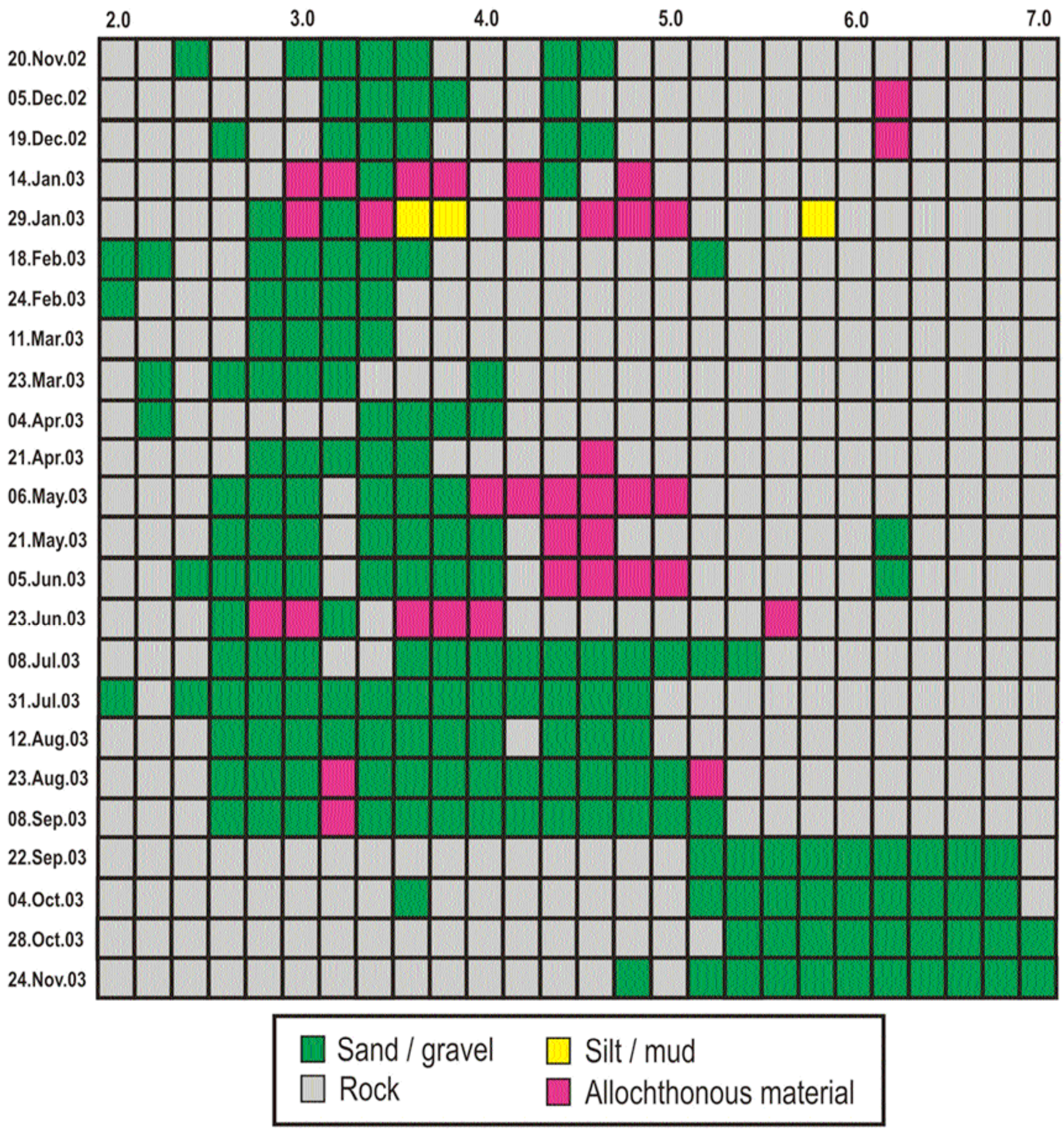

Fig. 10. Time series of the transect in Waiāhole Stream (transect indicated in 20-cm increments across the horizontal direction of the page), illustrating changes in substrate composition for the sampling times. Substrate changes are rapid, and long-lasting shifts occur suddenly.

of these periphyton growths for each stream is indicated in Table 1; however, in the transect identifications they were simply noted under the category of "periphyton" (Figs 12, 13). The floras of the two streams shared three taxa in common (the red algae *Audouinella eugenea* and *Compsopogon coeruleus* [which was reported as *Compsopogonopsis leptoclados* in previous HDAR studies by the author; taxonomic revision according to Rintoul et al. 1999], and the green alga *Cloniophora spicata*).

This study includes a number of new macroalgae records for Waiāhole Stream, even though the flora of the stream has been previously studied (Sherwood 2002b): *Microcoleus lacustris*, *Spirogyra* sp.

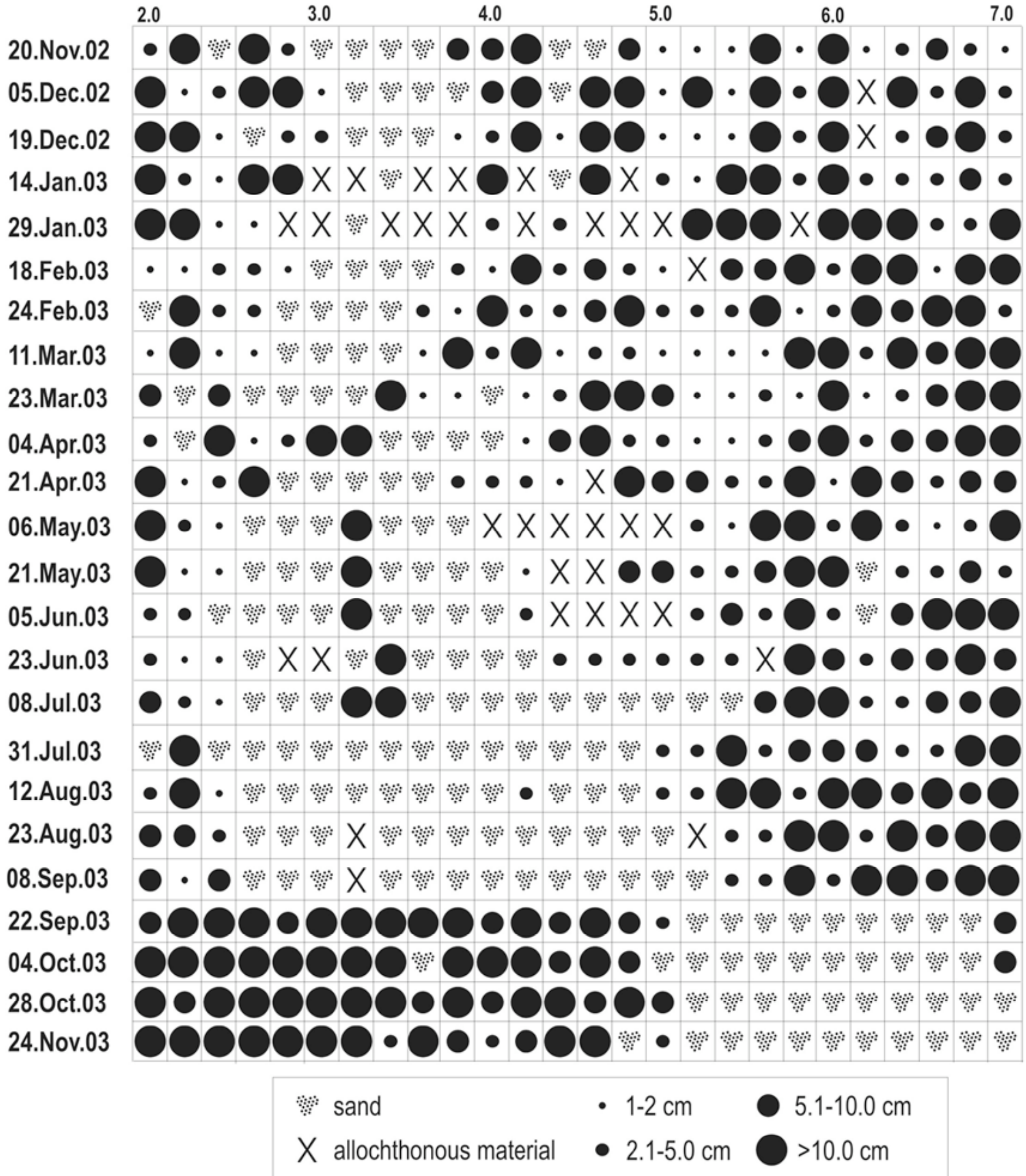

Fig. 11. Time series of changes in size of substrate for Waiāhole Stream. Changes in the areas of sand and allochthonous materials, which can occur rapidly, are especially evident from this illustration.

#80, *Stigeoclonium lubricum*, *Melosira varians*, *Pleurosira laevis* and *Terpsinōe musica*. The diatoms *Melosira varians* and *Pleurosira laevis* are the only new reports for Kahana Stream (based on records provided in Sherwood 2002b). Although Kahana Stream was identified in the previous study as having a much richer macroalgal flora than Waiāhole Stream, in the current study the two streams have an almost equal number of taxa in their transects. Thus, with repeated samplings over time it is possible to uncover more diversity than would be observed at any one sampling date; this illustrates the importance of longer term seasonality studies to Hawaiian stream algal floristics.

Algal Taxon	Waiāhole Stream	Kahana Stream
Cyanobacteria		
Microcoleus lacustris (Rabenh.) Farlow ex Farlow et al.	X	
Phormidium retzii (C.Agardh) Gomont		X
Chlorophyta		
Cloniophora spicata Schmidle emend. Islam	X	X
Spirogyra sp. #76		X
Spirogyra sp. #80	X	
Stigeoclonium lubricum (Dillwyn) Kūtz.	X	
Rhodophyta		
Audouinella eugenea (Skuja) Jao	X	X
Compsopogon coeruleus (Balbis) Mont.	X	X
Hildenbrandia angolensis Welw. ex W.West et G.S.West		X
Bacillariophyta		
Hydrosera whampoensis (Schwartz) Duby	X	X
Melosira varians C.Agardh	X	X
Pleurosira laevis (Ehrenb.) Compère	X	X
Synedra ulna (Nitzsch) Ehrenb.	X	X
Terpsinōe musica Ehrenb.	X	X

Table 1. Macroalgae identified from Waiāhole and Kahana Stream transects from November 2002 – November 2003.

Plate 1 (photos 1-13, next page). Photomicrographs of macroalgae and diatoms identified during the seasonality study in Waiāhole and Kahana Streams, O'ahu.

1. *Phormidium retzii* (C.Agardh) Gomont – filament diameter = 11.5 µm.
2. *Microcoleus lacustris* (Rabenh.) Farlow ex Farlow et al. diameter of individual trichome within common sheath = 6.3 µm.
3. *Audouinella eugenea* (Skuja) Jao – filament diameter = 10.0 µm.
4. *Compsopogon coeruleus* (Balbis) Mont. – filament diameter can vary widely, diameter here = 180 µm.
5. *Spirogyra* sp. #80 – filament diameter = 53.0 µm.
6. *Spirogyra* sp. #76 – filament diameter = 70.0 µm.
7. *Cloniophora spicata* Schmidle emend. Islam - diameter of main axis = 35.5 µm.
8. *Hildenbrandia angolensis* Welw. ex W.West et G.S.West – surface view of crust, cell diameter = 5.0 µm.
9. *Melosira varians* C.Agardh – chain of diatom cells, filament diameter = 23.0 µm.
10. *Terpsinōe musica* Ehrenb. – chain of diatom cells, cell diameter = ca. 70 µm.
11. *Stigeoclonium lubricum* (Dillwyn) Kūtz. – main axis diameter = 11.3 µm.
12. *Pleurosira laevis* (Ehrenb.) Compère – chain of diatom cells, cell diameter = 51.0 µm.
13. *Synedra ulna* (Nitzsch) Ehrenb. – cell length = 73 µm .

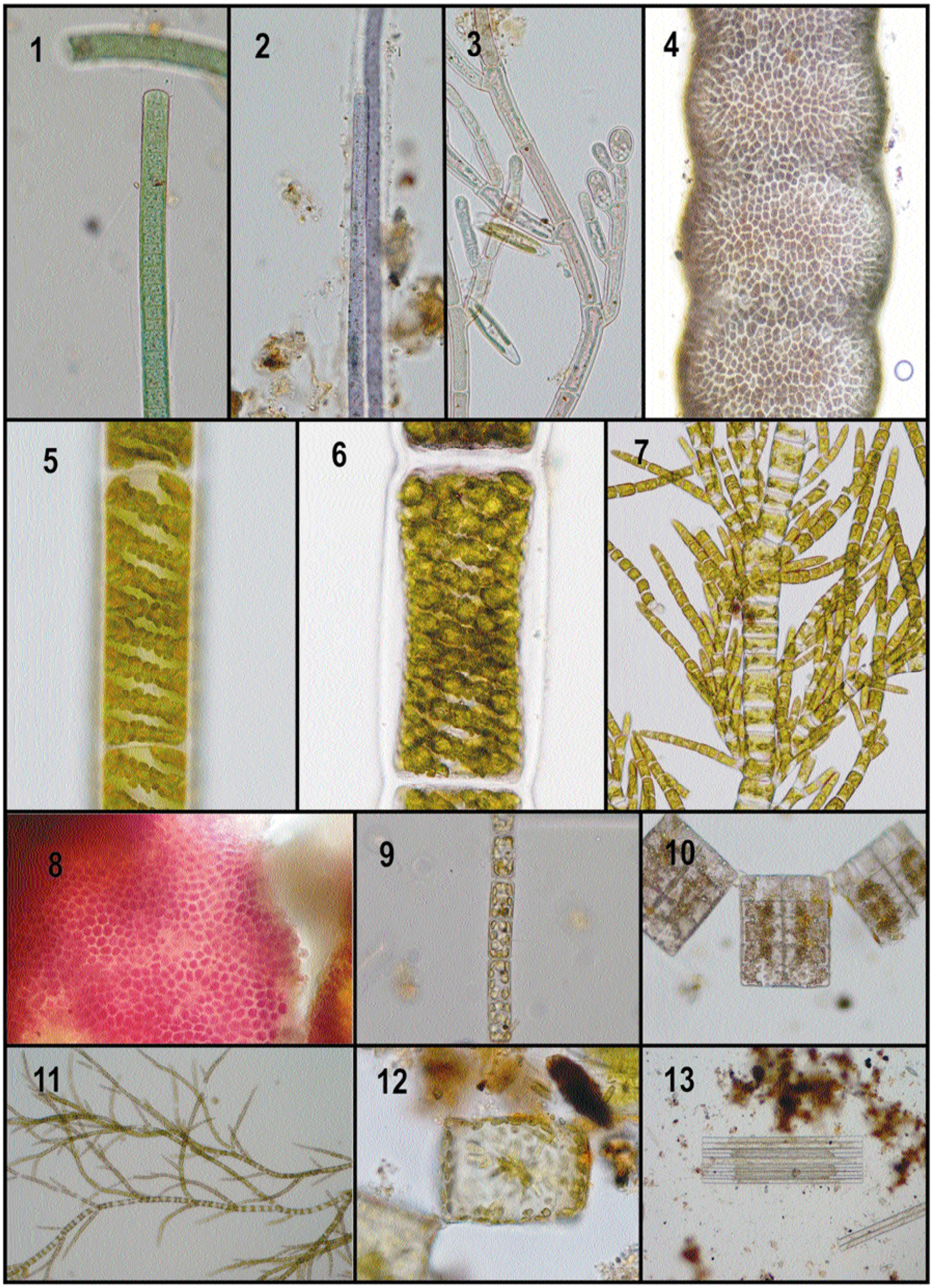

Plate 1. (See previous page)

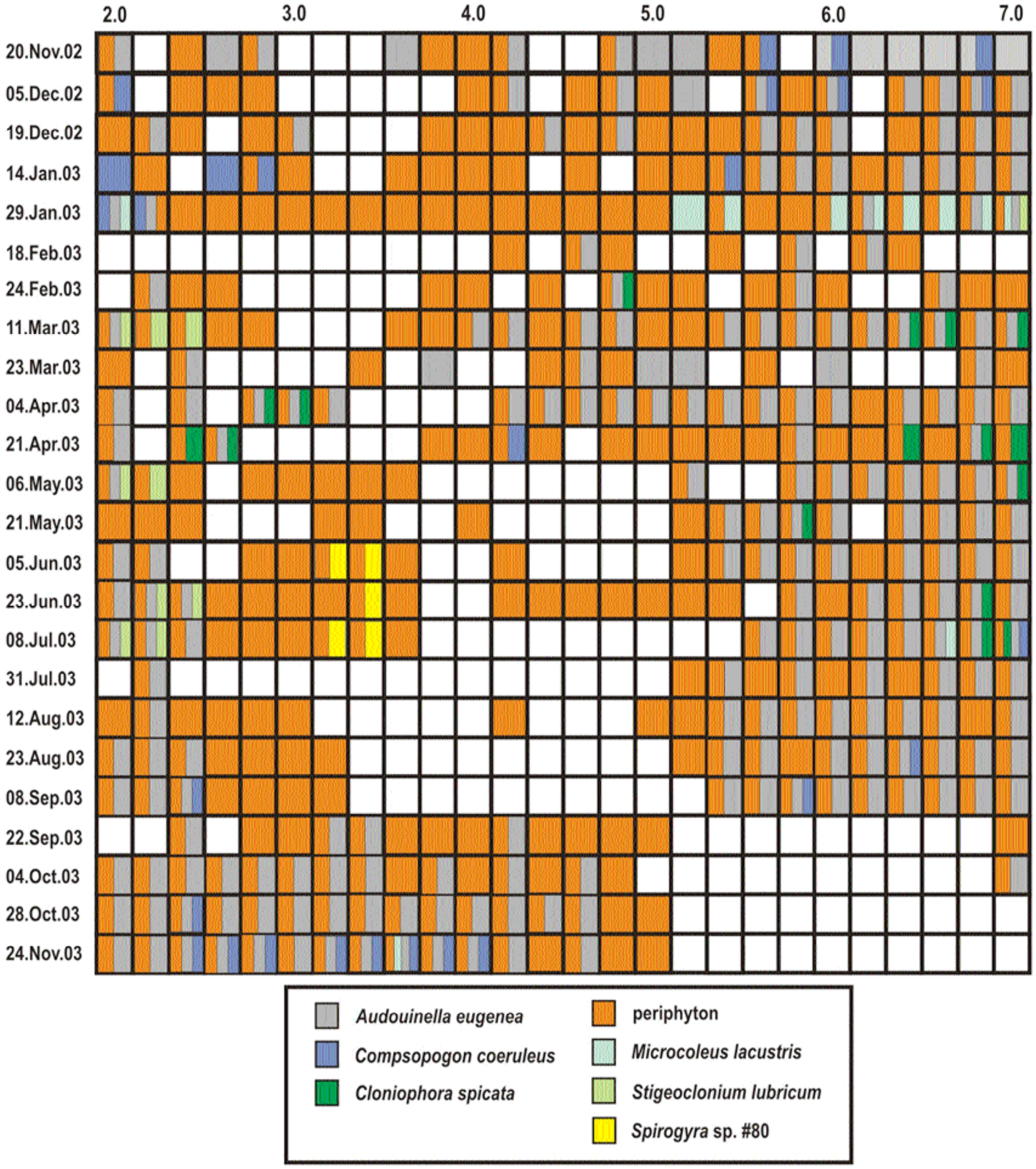

Fig. 12. Time series of changes in algal community composition for Waiāhole Stream. White boxes indicate the lack of algal cover at a particular transect point. Colored rectangles for each taxon indicate the presence of an alga at a particular transect point, and do not reflect proportional abundance of that taxon.

Figure 12 illustrates the changes in composition of the algal community at each 20-cm interval point for the Waiāhole Stream transect. It is immediately obvious from the figure that compositional changes occur rapidly within the stream. A gradual shift from periphyton and red algal dominance to periphyton and green algal dominance was seen as the sampling periods progressed from winter 2003 to summer 2003, followed by a decline in the number of green algae counts in the fall of 2003. The number of transect points with *Compsopogon* or *Audouinella* (red algae) present declined from 20.November.2002 until 29.January.2003. Between the 29.January.2003 and 18.February.2003 sampling periods a major rain

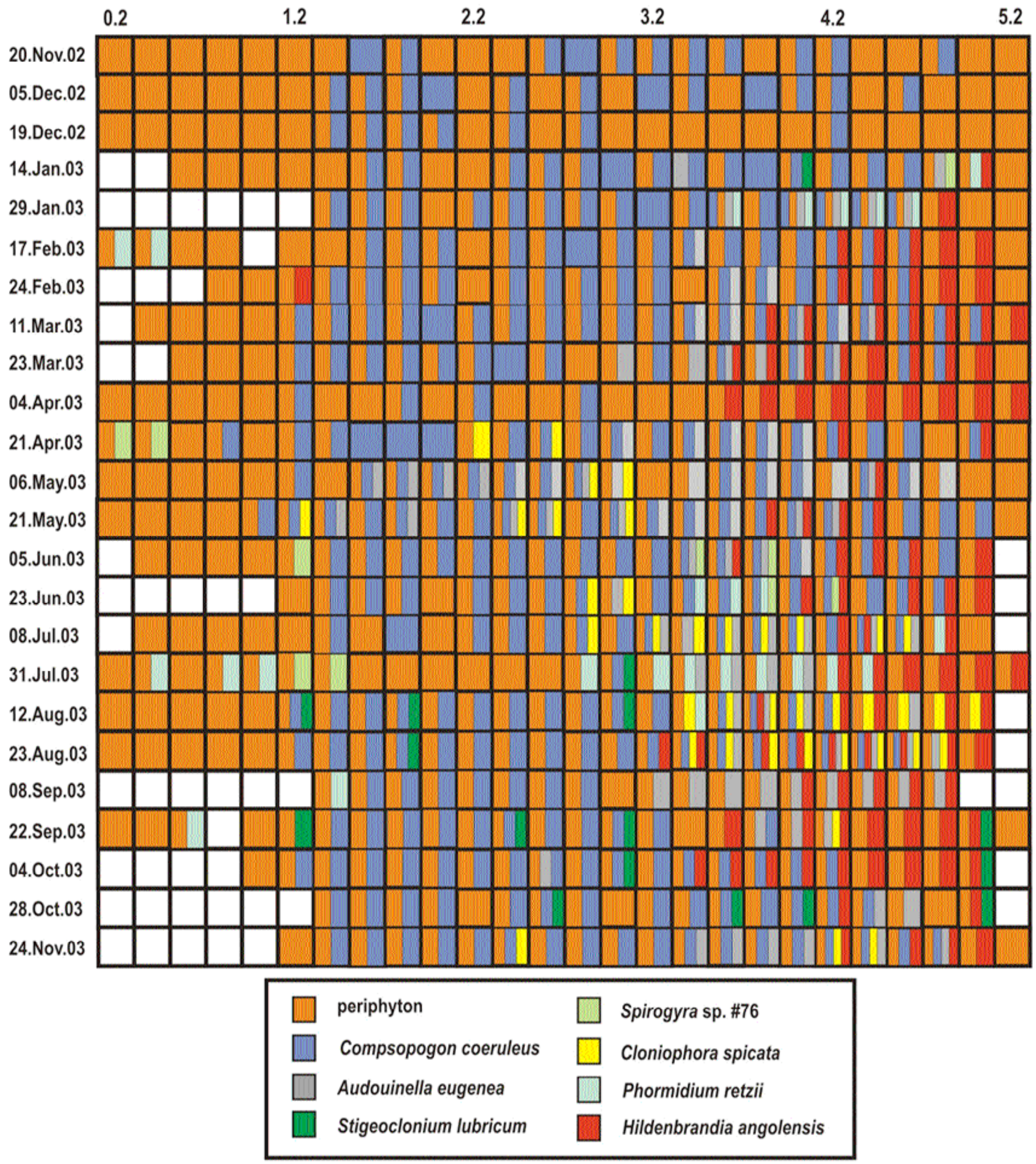

Fig. 13. Time series of changes in algal community composition for Kahana Stream. White boxes indicate the lack of algal cover at a particular transect point. Colored rectangles for each taxon indicate the presence of an alga at a particular transect point, and do not reflect proportional abundance of that taxon.

and flooding event severely affected the stream, resulting in scouring of the stream bottom, which can be seen in Figure 12 as an increase in the number of transect points with no visible algal cover (white boxes) for the 18.February.2003 sampling. The samplings following this flooding event (beginning 24.February.2003) revealed the presence of green algae in the stream transect (*Cloniophora spicata*, *Stigeoclonium lubricum* and *Spirogyra* sp. #80), and their presence was documented until mid-summer (July 2003). The algal cover data for the periods of April to June 2003 also illustrated the movement and overall increase in area of bare, sandy substrate. The 05.June.2003 sampling, however, revealed that the periphyton cover increased slightly due to its expansion over the sandy substrate. A large proportion of the transect points were again scoured clean of algal cover by the 31.July.2003 sampling period, although algal growth was noted in the subsequent sampling periods in the extremities of the exposed region. Following this scouring event, no green algae were noted in the transect, and for the remainder of the study, algal cover was predominantly composed of *Composopogon coeruleus*, *Audouinella eugenea* and periphyton cover. By the 22.September.2003 sampling, an additional morphological shift had occurred in the stream bed of the transect, such that the exposed area was shifted to the far right end of the transect. The effects of this morphological stream bed change remained present until the end of the study in November 2003.

Algal compositional changes for the Kahana Stream transect are illustrated in Figure 13. As for the Waiāhole Stream transect, compositional changes were rapid. Generally heavy periphyton growth was observed for the first three sampling periods, with no bare areas in the stream transect. The red alga *Compsopogon coeruleus* was the only other macroalga visible at the transect points for these sampling periods. The plant community in this transect was generally composed of mosses with overgrowing periphyton, attached *Compsopogon* plants, and occasional green algae or cyanobacteria either attached to the mosses or growing directly on the cement substrate. Water levels decreased in early January 2003, resulting in several bare transect points, and the establishment of a slightly more complex algal community, as indicated by the presence of additional algal taxa within the transect (*Phormidium retzii*, *Stigeoclonium lubricum*, *Spirogyra* sp. #76, *Audouinella eugenea* and *Hildenbrandia angolensis*). The flooding event in early February 2003, however, removed most of the green algal component of this community. The crustose red alga *Hildenbrandia angolensis* appeared to increase in frequency of presence from the early February 2003 sampling to the early April 2003 sampling; this was most likely a result of higher water levels and the frequency of rain events in the winter months removing the algal community overgrowing the crust. Thus, this distinctive alga most likely became highly visible in Kahana Stream when scouring of the periphyton overgrowth revealed the red color of the underlying *Hildenbrandia* crust. Following a regrowth of the periphyton cover in the latter part of April 2003 the observations of green algae in the transect also increased; however, these were mostly accounted for by *Cloniophora spicata*, rather than the green algae species observed earlier in the winter months of the study (*Stigeoclonium lubricum* and *Spirogyra* sp. #76). The slightly lower water levels of the 05.June.2003 sampling were also evident from the bare transect points on the far right and far left sections of the transect. *Cloniophora spicata* increased in frequency of occurrence into early July 2003. The 31.July.2003 sampling revealed decreased diversity across the transect, with large numbers of transect points having only periphyton cover, or a combination of periphyton and the cyanobacterium *Phormidium retzii*. The highest algal diversity in the transect was observed on 23.August.2003. A number of transect points were dry and bare from the end of August 2003 until the end of the study, except for the 22.September.2003 sampling.

Correlations among measured characters

Spearman correlations: Waiāhole Stream

In most cases, correlations among measured and determined stream characteristics for Waiāhole Stream were not significant. Four associations were determined to be significant, however, as shown in Table 2. Water pH and temperature were shown to be significantly and positively correlated, as were water temperature and daylength. Water temperature and mean water depth were significantly and negatively correlated, as well as mean water depth and daylength. Most of these correlations are not unexpected: water temperature is likely to be lower in the winter months (shorter daylength) and when greater amounts of water are present in the stream (greater mean depth). Additionally, mean water depth is likely to be lowest during the summer months (i.e. when daylength values are highest).

Association matrix	pH	Temperature	Specific conductance	Mean current velocity	Mean depth	Daylength
pH						
Temperature	(0.482) 0.017					
Specific conductance	—	—				
Mean current velocity	—	—	—			
Mean depth	—	(-0.650) 0.001	—	—		
Daylength	—	(0.589) 0.002	—	—	(-0.823) 0.001	

Table 2. Significant associations among measured and determined stream characters of Waiāhole Stream, based on the Spearman measure of rank correlation. The top number in parentheses is the correlation value, while the bottom number is the p-value.

Spearman correlations: Kahana Stream

Unlike the analyses for Waiāhole Stream, specific conductance values for Kahana Stream were negatively correlated with several other measured characters, such as mean current velocity and mean depth (Table 3). Water temperature was negatively correlated with mean current velocity and mean depth, which is not surprising given that lower temperatures are expected with greater amounts of water in the stream. Daylength and water temperature were positively correlated, which is reasonable considering that the longer days of the summer months are likely to result in increased water temperature. Mean current velocity and mean water depth were also significantly and positively correlated.

Association matrix	pH	Temperature	Specific conductance	Mean current velocity	Mean depth	Daylength
pH						
Temperature	(0.482) 0.017					
Specific conductance	—	—				
Mean current velocity	—	—	—			
Mean depth	—	(-0.650) 0.001	—	—		
Daylength	—	(0.589) 0.002	—	—	(-0.823) 0.001	

Table 3. Significant associations among measured and determined stream characters of Kahana Stream, based on the Spearman measure of rank correlation. The top number in parentheses is the correlation value, while the bottom number is the p-value.

Conclusions

The Waiāhole Stream transect underwent several major morphological shifts during the course of the study, such that large areas of the stream transect became "above water" with zero water depth and current velocity. Given that these changes were observed to occur several times during this 13-month study, it can be concluded that large changes in stream bed morphology are possible within relatively short periods of time. Shifts in the composition of the algal community appear to be related to the water depth and current velocity of the stream.

Compositional shifts in the stream algal communities of the two streams are rapid, and can occur in the time between two sampling periods (approximately two weeks in most cases). Likewise, the changes in substrate composition and substrate size for Waiāhole Stream were observed to occur very quickly, occurring on the same time scale as the algal community changes. Although the results of this study provide the most detailed examination of Hawaiian stream algal seasonality to date, a finer scale study at the sampling frequency of several days would allow more accurate correlation of changes in water flow and algal community composition.

Patterns in water depth and current velocity for Waiāhole and Kahana Streams differed to some degree, illustrating that the two streams may be under different influences. This highlights the need for multi-stream comparisons when attempting to generalize seasonal processes within the state of Hawai‘i.

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Appendix A. Depth recordings for each 20 cm interval across the transect in Waiāhole Stream, O'ahu, for the sampling intervals from November 2002 until November 2003. Depths are given in centimeters (cm).

Meter interval	20.Nov. 02	05.Dec. 02	19.Dec. 02	14.Jan. 03	29.Jan. 03	18.Feb. 03	24.Feb. 03	11.Mar. 03	23.Mar. 03	04.Apr. 03	21.Apr. 03	06.May. 03
2.0	26.0	23.0	26.0	29.0	27.0	28.0	26.0	23.0	18.0	27.5	21.0	19.0
2.2	24.0	26.5	20.0	30.0	29.0	26.0	24.0	22.0	9.0	27.0	19.0	15.0
2.4	25.0	26.5	27.5	28.0	27.0	22.0	20.5	18.0	16.0	28.0	19.0	15.0
2.6	22.0	22.0	27.0	25.0	26.0	21.0	18.0	16.0	16.0	26.0	16.0	12.0
2.8	19.0	17.0	24.0	20.0	22.0	19.0	18.0	14.5	13.0	24.0	13.0	9.0
3.0	17.0	16.0	19.0	18.0	20.0	18.0	13.0	12.0	8.5	19.0	10.5	8.0
3.2	18.0	15.0	16.0	17.0	16.5	16.0	8.0	9.0	8.0	18.5	8.0	5.0
3.4	17.0	13.0	15.0	15.0	15.0	9.0	8.0	6.0	7.0	15.0	7.0	3.0
3.6	15.0	10.5	14.0	15.0	14.0	9.0	9.0	7.0	8.0	16.0	5.0	2.0
3.8	10.0	8.5	11.0	12.0	11.0	10.0	8.0	5.0	4.5	13.0	3.5	0.5
4.0	10.0	7.0	9.0	10.0	10.0	7.0	7.0	6.0	3.5	10.0	1.5	0.5
4.2	6.0	4.0	8.0	7.0	8.0	7.0	7.0	5.0	2.5	10.0	1.0	0.5
4.4	6.0	5.0	6.0	7.0	5.0	6.0	6.0	7.0	4.0	10.0	1.0	0
4.6	4.0	6.0	5.0	8.0	7.0	7.0	6.5	8.0	7.0	11.0	1.5	0.5
4.8	8.0	7.0	7.5	9.0	7.5	7.0	6.0	5.5	7.0	9.0	0.5	0.5
5.0	13.0	7.0	10.0	9.0	8.0	6.0	5.0	6.0	6.5	8.5	3.0	0
5.2	12.0	12.0	11.0	12.0	10.0	5.0	5.0	6.5	5.0	8.5	4.0	2.0
5.4	6.0	5.0	12.0	8.0	9.0	6.0	6.0	6.5	6.0	10.5	7.0	5.0
5.6	1.0	2.0	0.0	2.0	0.0	7.0	7.0	6.0	10.0	11.0	7.0	1.5
5.8	13.0	12.0	13.0	12.0	12.0	3.0	3.5	7.0	8.0	8.5	5.0	4.0
6.0	12.0	10.0	11.0	10.0	11.0	6.0	4.0	6.5	9.5	10.5	9.0	6.0
6.2	15.0	14.0	13.0	13.0	13.0	7.0	6.5	8.0	8.0	12.0	8.0	7.0
6.4	21.0	18.0	16.0	17.0	16.0	9.0	9.0	9.0	8.0	13.0	9.5	7.0
6.6	22.0	20.0	19.0	20.0	18.0	11.0	11.0	9.0	7.0	13.0	11.0	9.5
6.8	25.0	21.0	20.0	19.0	19.0	9.0	11.5	9.5	7.0	14.0	9.5	6.0
7.0	24.0	24.0	23.0	23.0	21.0	14.0	13.0	13.0	8.5	15.0	11.5	10.0

Appendix A. Depth recordings for each 20 cm interval across the transect in Waiāhole Stream, O'ahu, for the sampling intervals from November 2002 until November 2003. Depths are given in centimeters (cm).

Meter interval	21.May. 03	05.Jun. 03	23.Jun. 03	08.July. 03	31.July. 03	12.Aug. 03	23.Aug. 03	08.Sep. 03	22.Sep. 03	04.Oct. 03	28.Oct. 03	24.Nov. 03
2.0	17.0	16.5	17.0	16.0	16.0	17.0	17.5	19.0	34.0	30.0	25.0	27.0
2.2	15.0	13.0	15.0	14.0	14.0	12.0	13.0	15.0	27.0	17.0	29.0	29.0
2.4	14.0	12.0	13.0	12.0	11.0	11.5	12.0	12.0	21.0	25.0	29.0	28.0
2.6	11.5	10.0	12.0	10.0	7.0	8.0	10.0	11.5	25.0	25.0	30.0	26.0
2.8	7.5	7.5	9.0	6.0	4.0	5.0	5.5	7.0	28.0	28.0	27.0	25.0
3.0	7.0	7.0	7.5	6.0	2.0	3.0	2.0	4.0	26.0	18.0	25.0	25.0
3.2	3.0	4.5	6.0	5.0	0	1.5	1.0	2.0	26.0	21.0	24.0	21.0
3.4	3.0	3.0	1.5	2.5	0	0	0	0	22.0	22.0	21.0	24.0
3.6	1.0	1.5	2.0	1.0	0	0	0	0	22.0	21.0	22.0	21.0
3.8	0	0	0	0	0	0	0	0	22.0	21.0	21.0	23.0
4.0	0.5	0	0	0	0	0	0	0	20.0	19.0	18.0	18.0
4.2	0	0	0	0	0	0.5	0	0	10.0	9.0	14.0	15.0
4.4	0.5	0	0	0	0	0	0	0	11.5	10.0	12.0	13.0
4.6	0	0	0	0	0	0	0	0	8.0	7.0	9.0	8.5
4.8	0	0	0	0	0	0	0	0	4.0	3.0	5.0	5.0
5.0	0	0	0	0	0.5	1.5	0	0	1.5	0	1.0	0.5
5.2	1.0	0	0	0	2.5	4.0	0.5	0	0	0	0	0
5.4	2.0	0.5	0	0	5.0	4.5	4.0	4.0	0	0	0	0
5.6	3.5	3.0	3.0	2.5	4.0	5.0	4.0	4.0	0	0	0	0
5.8	2.0	2.0	0	1.0	3.0	5.0	3.0	3.0	0	0	0	0
6.0	4.0	4.0	2.0	1.0	4.0	3.0	4.5	6.0	0	0	0	0
6.2	5.0	4.0	3.0	2.0	4.0	2.0	3.0	4.0	0	0	0	0
6.4	6.0	6.0	5.0	5.0	4.0	4.5	2.0	2.0	0	0	0	0
6.6	6.5	4.0	5.0	5.0	4.0	5.5	6.0	5.5	0	0	0	0
6.8	8.0	9.0	5.0	6.0	6.0	5.5	4.0	5.0	0	0	0	0
7.0	9.0	7.0	8.0	7.0	6.0	10.0	5.0	6.0	0	0	0	0

Appendix B. Depth recordings for each 20 cm interval across the transect in Kahana Stream, O'ahu, for the sampling intervals from November 2002 until November 2003. Depths are given in centimeters (cm).

Meter interval	20.Nov. 02	05.Dec. 02	19.Dec. 02	14.Jan. 03	29.Jan. 03	18.Feb. 03	24.Feb. 03	11.Mar. 03	23.Mar. 03	04.Apr. 03	21.Apr. 03	06.May. 03
0.2	1.0	0.0	0.0	0.0	0.0	1.0	0.2	0.0	0.0	2.0	0.5	0
0.4	2.0	0.5	0.0	0.5	0.0	2.0	0.5	0.0	0.5	8.0	2.0	0.5
0.6	1.0	0.0	0.0	0.5	0.0	1.0	0.5	0.0	0.5	7.0	1.0	0.5
0.8	1.0	0.0	0.0	0.0	0.0	0.5	3.0	0.0	0.0	10.0	0.5	0
1.0	2.0	0.5	0.0	0.0	0.0	1.5	1.0	0.0	0.5	8.5	0.5	0.5
1.2	3.0	0.5	0.5	0.5	0.0	3.0	1.5	1.0	2.0	9.0	2.0	0.5
1.4	4.0	2.0	1.0	1.0	1.0	2.0	2.0	1.5	1.5	11.0	2.0	1.0
1.6	2.0	2.0	2.0	2.0	1.0	5.0	4.5	4.0	4.0	13.5	5.0	2.5
1.8	3.0	2.5	3.0	1.0	2.0	5.0	3.5	3.0	2.5	13.5	4.0	3.0
2.0	2.0	1.0	1.5	2.0	0.5	6.0	3.5	5.0	3.5	12.5	6.0	2.0
2.2	4.0	3.5	3.0	2.0	1.5	5.0	4.0	2.0	4.0	11.0	4.0	5.0
2.4	7.0	5.0	8.0	8.0	7.0	11.0	6.0	10.0	7.5	14.0	9.5	8.0
2.6	5.0	5.0	5.0	8.0	4.0	11.0	7.0	8.0	10.0	16.0	10.0	7.0
2.8	8.0	7.0	6.0	7.0	4.0	8.0	6.0	7.0	7.0	15.0	12.0	7.0
3.0	7.0	4.0	6.0	8.0	4.0	11.0	7.0	10.5	7.0	16.0	11.0	4.0
3.2	22.0	20.0	18.0	19.0	16.0	22.0	22.0	18.0	19.0	35.0	21.0	22.0
3.4	20.0	19.0	19.0	18.0	17.0	21.0	21.0	20.0	19.0	28.0	20.0	17.0
3.6	18.0	15.0	16.0	17.0	15.0	17.0	19.0	17.0	16.0	29.0	17.0	16.0
3.8	15.0	13.0	13.0	14.0	12.0	16.0	17.0	14.0	14.0	28.0	15.0	13.0
4.0	14.0	12.0	12.0	14.0	10.0	13.0	14.0	12.0	12.0	23.0	13.0	10.5
4.2	12.0	11.0	10.0	12.0	8.0	12.0	12.0	10.5	10.0	19.0	11.0	10.0
4.4	10.0	9.0	7.0	10.0	6.0	11.0	10.0	8.5	9.5	17.5	10.0	8.5
4.6	8.0	6.0	6.0	6.0	4.0	9.0	8.0	5.5	6.5	15.0	9.0	6.5
4.8	7.0	3.0	3.0	3.0	1.5	7.0	6.0	5.5	4.5	13.0	7.0	4.0
5.0	4.0	1.0	0.5	0.5	0.0	4.0	5.0	2.5	2.0	13.0	4.5	1.0
5.2	1.0	0.0	0.0	0.0	0.0	3.0	1.5	0.0	0.5	10.0	2.0	0

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0.2	0	0	0	0	0.5	0	0	0	0.5	0	0	0
0.4	0.5	0	0	0	2.0	0	0	0	1.0	0	0	0
0.6	0.5	0	0	0	2.5	0	0	0	1.0	0	0	0
0.8	0.5	0	0	0	4.0	0	0	0	0.5	0	0	0
1.0	0.5	0	0	0	2.5	0.5	0	0	1.0	0	0	0
1.2	2.0	0.5	0.5	0	3.5	0.5	0.5	0	3.0	1.0	0	0.5
1.4	2.5	0.5	0.5	1.5	3.0	2.0	1.0	0.5	2.0	2.0	1.0	1.0
1.6	3.0	2.0	1.0	1.5	5.0	2.0	2.0	0.5	4.0	2.0	0.5	1.5
1.8	3.0	3.0	2.0	2.0	6.0	3.5	3.0	2.0	5.0	3.0	2.0	2.0
2.0	2.0	0.5	0.5	0	4.0	1.0	1.0	0	2.0	0.5	1.0	2.5
2.2	5.0	4.0	2.0	3.0	6.0	4.5	5.0	2.0	6.0	3.0	2.0	3.0
2.4	6.0	8.0	6.0	5.0	12.0	5.0	4.0	5.0	10.0	6.0	6.0	7.5
2.6	5.5	6.0	7.0	8.0	12.0	9.0	7.0	7.0	9.0	6.0	8.0	3.0
2.8	6.0	7.0	6.0	4.0	12.0	6.5	6.0	6.0	8.0	6.0	5.0	6.5
3.0	5.0	6.0	2.0	3.0	13.0	4.0	3.5	3.0	6.0	2.0	3.0	3.0
3.2	20.5	19.5	17.0	18.0	23.0	20.0	20.0	18.0	22.0	18.0	17.0	19.0
3.4	18.0	15.0	15.0	15.0	21.0	16.0	15.0	14.0	20.0	15.0	16.0	17.5
3.6	15.0	14.0	14.0	13.0	19.0	15.0	13.0	13.0	18.0	13.0	14.0	15.0
3.8	13.0	12.0	10.0	11.0	16.0	12.0	11.0	11.0	15.0	11.0	12.0	13.0
4.0	12.0	10.0	9.0	9.0	13.0	10.0	10.5	10.0	13.0	10.0	12.0	11.0
4.2	10.5	8.0	8.0	7.0	12.0	9.0	8.0	8.0	11.0	8.0	9.0	10.0
4.4	9.0	7.0	6.0	6.0	9.5	6.5	6.0	6.0	10.0	7.0	8.0	8.0
4.6	7.0	5.0	4.0	2.0	7.5	5.0	4.0	3.0	8.0	5.0	5.0	6.5
4.8	4.0	3.0	1.5	0	5.5	1.5	1.0	0	6.5	2.0	0.5	3.5
5.0	2.0	0	0	0	4.0	0	0	0	4.0	0	0	0.5
5.2	0	0	0	0	2.0	0	0	0	0.5	0	0	0

Appendix C. Current velocity readings for each 20 cm interval across the transect in Waiāhole Stream, O'ahu, for the sampling intervals from November 2002 until November 2003. Velocities are given in cm/sec.

Meter interval	20.Nov. 02	05.Dec. 02	19.Dec. 02	14.Jan. 03	29.Jan. 03	18.Feb. 03	24.Feb. 03	11.Mar. 03	23.Mar. 03	04.Apr. 03	21.Apr. 03	06.May. 03
2.0	32.0	18.0	22.0	13.0	50.0	39.0	60.0	58.0	48.0	29.0	56.0	58.0
2.2	22.0	18.0	23.0	23.0	80.0	53.0	50.0	53.0	13.0	65.0	57.0	50.0
2.4	16.0	36.0	28.0	22.0	26.0	62.0	42.0	51.0	28.0	37.0	58.0	33.0
2.6	20.0	30.0	34.0	47.0	9.0	44.0	28.0	39.0	13.0	64.0	37.0	0.0
2.8	25.0	12.0	51.0	5.0	0.0	39.0	19.0	26.0	10.0	38.0	13.0	0.0
3.0	12.0	5.0	28.0	0.0	10.0	23.0	0.0	6.0	5.0	52.0	0.0	0.0
3.2	10.0	5.0	5.0	0.0	0.0	23.0	0.0	0.0	0	18.0	0.0	0.0
3.4	0.0	0.0	5.0	0.0	0.0	10.0	0.0	0.0	0	21.0	0.0	0.0
3.6	0.0	0.0	5.0	0.0	0.0	10.0	14.0	0.0	0	28.0	0.0	0.0
3.8	0.0	0.0	0.0	0.0	0.0	45.0	58.0	78.0	19.0	15.0	0.0	0.0
4.0	13.0	0.0	0.0	0.0	0.0	75.0	57.0	76.0	10.0	15.0	10.0	0.0
4.2	0.0	0.0	0.0	0.0	0.0	72.0	61.0	87.0	10.0	41.0	9.0	0.0
4.4	0.0	5.0	0.0	0.0	0.0	77.0	59.0	52.0	45.0	29.0	8.0	0.0
4.6	0.0	5.0	5.0	0.0	0.0	52.0	64.0	46.0	100.0	68.0	9.0	0.0
4.8	57.0	41.0	16.0	0.0	0.0	68.0	53.0	47.0	93.0	79.0	8.0	0.0
5.0	40.0	42.0	38.0	0.0	0.0	86.0	38.0	51.0	46.0	111.0	10.0	0.0
5.2	43.0	40.0	37.0	0.0	0.0	63.0	58.0	44.0	65.0	75.0	45.0	20.0
5.4	28.0	40.0	48.0	0.0	0.0	72.0	40.0	67.0	64.0	64.0	65.0	60.0
5.6	0.0	0.0	0.0	0.0	0.0	66.0	90.0	34.0	45.0	78.0	100.0	38.0
5.8	58.0	32.0	41.0	0.0	0.0	58.0	76.0	63.0	65.0	94.0	113.0	57.0
6.0	34.0	37.0	40.0	0.0	0.0	78.0	55.0	45.0	84.0	68.0	97.0	66.0
6.2	0.0	33.0	36.0	0.0	32.0	70.0	82.0	55.0	90.0	97.0	81.0	68.0
6.4	10.0	14.0	0.0	0.0	34.0	104.0	78.0	67.0	80.0	112.0	97.0	82.0
6.6	40.0	34.0	45.0	10.0	28.0	105.0	96.0	100.0	110.0	93.0	84.0	108.0
6.8	51.0	68.0	89.0	50.0	48.0	107.0	141.0	107.0	95.0	102.0	69.0	73.0
7.0	46.0	49.0	41.0	57.0	56.0	101.0	128.0	111.0	106.0	101.0	75.0	73.0

Appendix C. Current velocity readings for each 20 cm interval across the transect in Waiāhole Stream, O‘ahu, for the sampling intervals from November 2002 until November 2003. Velocities are given in cm/sec.

Meter interval	21.May. 03	05.Jun. 03	23.Jun. 03	08.July. 03	31.July. 03	12.Aug. 03	23.Aug. 03	08.Sep. 03	22.Sep. 03	04.Oct. 03	28.Oct. 03	24.Nov. 03
2.0	37.0	44.0	44.0	42.0	12.0	23.0	23.0	45.0	63.0	23.0	72.0	55.0
2.2	34.0	24.0	42.0	36.0	12.0	24.0	18.0	40.0	71.0	52.0	38.0	39.0
2.4	12.0	0.0	28.0	0.0	13.0	0.0	16.0	25.0	52.0	33.0	21.0	38.0
2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59.0	28.0	50.0	33.0
2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.0	5.0	21.0	41.0
3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.0	13.0	28.0	31.0
3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.0	23.0	25.0	22.0
3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.0	31.0	34.0	24.0
3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.0	25.0	20.0	27.0
3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.0	22.0	22.0	12.0
4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.0	11.0	26.0	24.0
4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	28.0	18.0	13.0
4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.0	21.0	29.0	24.0
4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.0	11.0	21.0	21.0
4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0
5.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0
5.2	15.0	0.0	0.0	0.0	42.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0
5.4	17.0	15.0	0.0	0.0	34.0	37.0	32.0	37.0	0.0	0.0	0.0	0.0
5.6	20.0	20.0	20.0	31.0	36.0	39.0	20.0	18.0	0.0	0.0	0.0	0.0
5.8	38.0	20.0	25.0	27.0	44.0	18.0	37.0	21.0	0.0	0.0	0.0	0.0
6.0	29.0	35.0	22.0	28.0	34.0	32.0	37.0	23.0	0.0	0.0	0.0	0.0
6.2	38.0	42.0	35.0	29.0	33.0	32.0	39.0	35.0	0.0	0.0	0.0	0.0
6.4	48.0	57.0	30.0	34.0	25.0	36.0	36.0	50.0	0.0	0.0	0.0	0.0
6.6	58.0	71.0	75.0	82.0	21.0	36.0	23.0	35.0	0.0	0.0	0.0	0.0
6.8	96.0	52.0	83.0	75.0	53.0	64.0	46.0	48.0	0.0	0.0	0.0	0.0
7.0	87.0	83.0	66.0	101.0	48.0	53.0	52.0	39.0	0.0	13.0	0.0	0.0

Appendix D. Current velocity readings for each 20 cm interval across the transect in Kahana Stream, O'ahu, for the sampling intervals from November 2002 until November 2003. Velocities are given in cm/sec.

Meter interval	20.Nov. 02	05.Dec. 02	19.Dec. 02	14.Jan. 03	29.Jan. 03	18.Feb. 03	24.Feb. 03	11.Mar. 03	23.Mar. 03	04.Apr. 03	21.Apr. 03	06.May. 03
0.2	2.0	0.0	0.0	0.0	0.0	10.0	0.0	5.0	0.0	220.0	15.0	0.0
0.4	2.0	0.0	0.0	0.0	0.0	10.0	10.0	5.0	5.0	229.0	15.0	5.0
0.6	2.0	0.0	0.0	0.0	0.0	10.0	5.0	5.0	0	219.0	15.0	5.0
0.8	2.0	0.0	0.0	0.0	0.0	34.0	10.0	5.0	0	209.0	15.0	5.0
1.0	5.0	0.0	0.0	0.0	0.0	10.0	10.0	10.0	0	207.0	20.0	5.0
1.2	30.0	0.0	5.0	10.0	0.0	120.0	82.0	15.0	37.0	228.0	81.0	10.0
1.4	39.0	0.0	5.0	30.0	20.0	112.0	83.0	77.0	55.0	239.0	51.0	100.0
1.6	102.0	85.0	60.0	97.0	25.0	168.0	149.0	110.0	127.0	250.0	135.0	134.0
1.8	78.0	88.0	83.0	59.0	30.0	170.0	155.0	140.0	138.0	224.0	162.0	134.0
2.0	108.0	85.0	51.0	42.0	15.0	154.0	163.0	136.0	150.0	232.0	169.0	75.0
2.2	79.0	54.0	72.0	89.0	40.0	159.0	135.0	11.0	97.0	275.0	142.0	117.0
2.4	105.0	85.0	94.0	124.0	94.0	168.0	176.0	133.0	109.0	260.0	137.0	163.0
2.6	84.0	94.0	112.0	138.0	99.0	133.0	197.0	137.0	116.0	230.0	155.0	146.0
2.8	107.0	103.0	104.0	135.0	108.0	170.0	178.0	144.0	145.0	256.0	168.0	161.0
3.0	93.0	72.0	79.0	84.0	62.0	169.0	182.0	130.0	134.0	256.0	163.0	131.0
3.2	160.0	140.0	150.0	182.0	178.0	210.0	201.0	182.0	183.0	249.0	195.0	193.0
3.4	151.0	141.0	133.0	160.0	167.0	204.0	199.0	185.0	189.0	240.0	196.0	189.0
3.6	141.0	133.0	127.0	130.0	153.0	193.0	200.0	179.0	179.0	278.0	186.0	182.0
3.8	133.0	119.0	129.0	166.0	139.0	177.0	167.0	152.0	169.0	282.0	176.0	181.0
4.0	136.0	117.0	118.0	152.0	134.0	193.0	179.0	173.0	178.0	268.0	185.0	153.0
4.2	130.0	100.0	109.0	134.0	115.0	187.0	167.0	151.0	168.0	259.0	164.0	149.0
4.4	111.0	85.0	97.0	93.0	91.0	172.0	164.0	126.0	153.0	242.0	151.0	139.0
4.6	108.0	65.0	74.0	66.0	42.0	154.0	102.0	111.0	131.0	215.0	146.0	113.0
4.8	77.0	0.0	5.0	26.0	0.0	148.0	113.0	50.0	109.0	204.0	128.0	82.0
5.0	35.0	0.0	0.0	10.0	0.0	123.0	83.0	20.0	15.0	181.0	110.0	10.0
5.2	5.0	0.0	0.0	0.0	0.0	46.0	10.0	0	5.0	178.0	20.0	0.0

Appendix D. Current velocity readings for each 20 cm interval across the transect in Kahana Stream, O'ahu, for the sampling intervals from November 2002 until November 2003. Velocities are given in cm/sec.

Meter interval	21.May. 03	05.Jun. 03	23.Jun. 03	08.July. 03	31.July. 03	12.Aug. 03	23.Aug. 03	08.Sep. 03	22.Sep. 03	04.Oct. 03	28.Oct. 03	24.Nov. 03
0.2	0.0	0.0	0.0	0.0	57.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0
0.4	15.0	5.0	0.0	0.0	60.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0
0.6	15.0	0.0	0.0	0.0	80.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0
0.8	0.0	0.0	0.0	0.0	52.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0
1.0	15.0	0.0	0.0	0.0	79.0	15.0	0.0	0.0	2.5	0.0	0.0	0.0
1.2	15.0	15.0	0.0	0.0	106.0	25.0	15.0	0.0	7.1	11.0	0.0	15.0
1.4	93.0	105.0	86.0	63.0	106.0	60.0	67.0	26.0	6.3	57.0	3.0	41.0
1.6	142.0	118.0	54.0	50.0	122.0	60.0	69.0	10.0	9.6	20.0	33.0	52.0
1.8	155.0	129.0	76.0	45.0	120.0	60.0	62.0	21.0	10.8	48.0	30.0	58.0
2.0	101.0	90.0	35.0	25.0	111.0	75.0	15.0	0.0	8.3	44.0	0.0	70.0
2.2	115.0	83.0	72.0	96.0	123.0	65.0	70.0	48.0	9.5	53.0	38.0	58.0
2.4	132.0	127.0	142.0	136.0	93.0	88.0	86.0	78.0	6.8	88.0	79.0	77.0
2.6	171.0	136.0	129.0	135.0	133.0	89.0	86.0	69.0	11.5	85.0	72.0	88.0
2.8	175.0	162.0	133.0	141.0	136.0	95.0	91.0	81.0	12.0	84.0	73.0	82.0
3.0	160.0	135.0	92.0	123.0	124.0	96.0	92.0	41.0	10.7	64.0	58.0	63.0
3.2	195.0	185.0	192.0	178.0	140.0	120.0	118.0	115.0	12.4	115.0	110.0	115.0
3.4	200.0	182.0	180.0	177.0	142.0	112.0	112.0	106.0	15.0	113.0	106.0	114.0
3.6	167.0	162.0	151.0	152.0	118.0	106.0	106.0	100.0	10.5	100.0	102.0	102.0
3.8	180.0	172.0	155.0	169.0	112.0	111.0	108.0	103.0	12.4	100.0	98.0	101.0
4.0	172.0	165.0	153.0	156.0	116.0	104.0	100.0	98.0	11.4	99.0	99.0	96.0
4.2	165.0	146.0	131.0	141.0	111.0	96.0	91.0	86.0	10.5	89.0	91.0	91.0
4.4	140.0	132.0	119.0	116.0	113.0	82.0	74.0	73.0	10.2	74.0	68.0	82.0
4.6	123.0	109.0	81.0	35.0	92.0	62.0	59.0	12.0	9.6	55.0	53.0	59.0
4.8	97.0	20.0	0.0	0.0	91.0	15.0	15.0	0.0	8.1	12.0	5.0	25.0
5.0	15.0	0.0	0.0	0.0	79.0	0.0	0.0	0.0	6.8	0.0	0.0	5.0
5.2	0.0	0.0	0.0	0.0	35.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0