

## Abstracts of Papers

Twenty-sixth Annual Albert L. Tester Memorial Symposium, 11–12 April 2001<sup>1</sup>

The Albert L. Tester Memorial Symposium is held in honor of Professor Albert Tester, who, at the time of his death in 1974, was senior professor of zoology at the University of Hawai'i at Mānoa. The faculty and students of the Department of Zoology proposed an annual symposium of student research papers as a means of honoring, in a continuing and active way, Dr. Tester's lively encouragement of student research in a broad range of fields within marine biology. Papers reporting original research on any aspect of science are solicited from students at the university and these papers are presented at the symposium, which takes place during the spring semester. Income from contributions to the Albert L. Tester Memorial Fund of the University of Hawai'i Foundation is used to provide prizes for the two best papers, judged on quality, originality, and importance of research reported, as well as the quality of the public presentation. The Waikiki Aquarium presents the Mike Weekley Award, based on the same criteria. Judges include Department of Zoology faculty members and the previous year's student award winners. In addition, a distinguished scholar from another university or research institution is invited to participate in the symposium as a judge and to present the major symposium address. This year the guest participant was Steve Jones, University College, London.

### Contact Dermatitis Outbreak on the University of Hawai'i Campus<sup>2</sup>

Dianna M. Appelgate<sup>3</sup>

On 22 August 2000 the University of Hawai'i's Health Care Center received the first of several cases of contact dermatitis with clinical presentation similar to that from contact with plants of the genus *Rhus* (poison oak, ivy, sumac). The majority of cases resided in a single dormitory (Noelani Dormitory). Because Hawai'i has few poisonous plants and no record of the poisonous species of *Rhus*, an outbreak investigation was initiated. Cases

were defined as anyone with contact dermatitis, after 7 August, on the University of Hawai'i campus. A total of 106 students (53 cases/53 controls) from Noelani was asked questions regarding exposure to plants, exposure to other areas on campus, clothing, current oral medication, and previous allergies. Gender and age were not significantly associated with contact dermatitis. Ethnically, 58.7% of cases were Caucasian, significantly different from controls (38% Caucasian). Rates for those who had recently been in the Noelani courtyard were 56.3%, and 26.2% for those who had not. UH botanical experts identified two *Semecarpus nigroviridis* (marking nut) trees in the Noelani courtyard. The trees were cut down on 22 September and the last case was reported on 24 September. The association with the courtyard, the removal of the trees, and that *S. nigroviridis* contains anacardic acid documented to cause contact dermatitis strongly suggest that the trees were the source of the outbreak. The high per-

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centage of Caucasian cases supports the possible effect of desensitization by previous ex-

posure to plants in the same family consumed by local residents.

### Geographic Variations in the Whistle Repertoire of Hawaiian Spinner Dolphins (*Stenella longirostris*)<sup>4</sup> Carmen Bazúa-Durán<sup>5</sup>

Studying geographic variations in the whistle repertoire of spinner dolphins (*Stenella longirostris*) will increase our understanding of the population structure of this species. In this study, groups of spinner dolphins off five Hawaiian Islands, Midway, Kaua'i, O'ahu, Lāna'i, and Hawai'i, were surveyed, as well as groups of spinners off Mo'orea, French Polynesia. The whistle repertoire of dolphin groups from Kaua'i, O'ahu, Lāna'i, and Hawai'i was compared to search for microgeographic variations, and the whistle repertoire of all Hawaiian Islands spinner dolphins was compared with the repertoire of dolphins off Mo'orea to search for macrogeographic variations. Frequency and time information was

extracted from the spectrogram of each whistle, and this information was used to search for differences between groups. Results show that micro- and macrogeographic variations exist in the whistle repertoire of spinner dolphins. Statistically significant differences were obtained by comparing the whistle repertoires using discriminant function analysis. Although macrogeographic variations were found, geographic differences may not exist in the spinner dolphin whistle repertoire. The existence of microgeographic variations indicates that dialects may exist in the spinner dolphin whistle repertoire and that the Kaua'i population may be different from the other main Hawaiian Island spinner dolphins.

### Horizontal Angular Discrimination by an Echolocating Bottlenose Dolphin (*Tursiops truncatus*)<sup>6</sup> Brian Branstetter<sup>7</sup>

A bottlenose dolphin was tested on its ability to echoically discriminate horizontal angular differences between two arrays of vertical, air-filled, PVC rods. The blindfolded dolphin

was required to station in a submerged vertically oriented hoop 2 radial meters from the stimuli and indicate if an array with four rods (S+) was to the left or the right of an array with two rods (S-) by pressing a corresponding paddle. The rods within each array were separated by 2 degrees and the two arrays were separated by eight different angles between 2.25 degrees and 6 degrees. A modified method of constant stimuli was used to test for angular discrimination ability. The results yielded a high-pass psychometric function with an arbitrary 75% correct threshold of 1.6 degrees. These data agree well with passive listening minimum audible angle thresholds of 0.9 degrees for click signals and 2.1 degrees for a pure tone signal. Analyses of response times, number of clicks, and inter-click intervals suggested that no significant adaptive

<sup>4</sup> This work was supported by a Leonida Memorial Scholarship, a Seed Money Grant from the University of Hawai'i, and a University of Hawai'i Foundation Grant. C.B.-D. is a Fulbright-García Robles-CONACyT and DGAPA fellow.

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<sup>6</sup> Thanks to the "Angular Res. Crew," the many interns, staff, participants, and docs at the Kewalo Basin Marine Mammal Laboratory, and funding from Earthwatch and The Dolphin Institute.

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behavior was used as the task became more difficult. These results help define angular resolution capabilities of dolphin sonar that

may play an important role in representing spatial information in the dolphin's environment.

### **Coral Recruitment Patterns at Selected Sites around West Maui**

*Eric K. Brown<sup>8</sup>*

Recruitment, growth, and mortality of coral larvae were examined using unglazed terracotta tiles as settlement plates. Seven settlement plate arrays (two plate pairs affixed to a stake: one vertical, one horizontal) were installed in March 1999 at six reef areas (spatial scale 100 m) across three sites (spatial scale 5–10 km) on Maui. Arrays were retrieved every 4 to 5 months from each reef and analyzed for number of new coral recruits, size of individual colonies, and mortality. Plates were returned to the reef and affixed to the array in the same location and orientation. A second set of plates was installed on the existing arrays in March–April 2000. At the site level, Puamana had the highest number of recruits and Honolulu had the lowest, with Olowalu intermediate. There was no significant difference in number of recruits at the reef level.

Vertical plates had higher recruitment levels than horizontal plates, but this was dependent on the reef. Colonies at Puamana had the greatest change in size for all genera compared with Honolulu, with Olowalu intermediate. Olowalu, however, had the highest proportion of mortality, followed closely by Puamana, with Honolulu having the lowest. Total number of surviving recruits was significantly different among sites, with Puamana having the highest number, followed by Olowalu and Honolulu. Sexual recruitment in this study supports historical trends in coral cover over the last 6 yr, with cover increasing at Puamana (from 3 to 9%), staying constant at Olowalu (from 32 to 39%), and declining at Honolulu (from 42 to 18%). This suggests that these sites may be recruitment limited.

### **Modulation of Adhesion Molecules by TNF- $\alpha$ and Salicylic Acid in Human Coronary Artery Endothelial Cells: Pathogenic Mechanisms in Kawasaki Syndrome<sup>9</sup>**

*Pong Kian Chua<sup>10</sup>*

Kawasaki syndrome (KS), an acute febrile illness of unknown etiology affecting infants and young children, is characterized by vascular inflammation of coronary arteries and other medium-sized muscular arteries, leading to coronary aneurysms and thromboses.

Infiltration of immune cells into the intima and adventitia are observed in autopsy tissues. Treatment for KS includes high-dose aspirin (salicylic acid) and IVIG. Using primary human coronary artery endothelial cell cultures (HCAEC), we performed semi-quantitative RT-PCR and cell-based ELISA and found that TNF- $\alpha$  increased levels of adhesion molecules ICAM-1 and E-selectin as well as MCP-1 in a time- and dose-dependent manner, and this increase was inhibited by salicylic acid (NaSal). Furthermore, the signaling events involved the transcription factor NF- $\kappa$ B. These results indicate a possible pathogenic mechanism in KS, whereby immune cells are attracted to sites of inflammation,

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undergo extravasation, and release enzymes, such as metalloproteinases, into the extracellular matrix that assist in vascular remodeling, thereby weakening the endothelium and hastening the process of aneurysm. NaSal, in

addition to preventing thrombosis and lowering fever in KS, may also function in down-regulating adhesion molecules during the inflammatory stage in KS.

## Geochemistry of Plume-Ridge Interaction at the Galápagos Spreading Center

*Buffy J. Cushman*<sup>11</sup>

To assess the effects of a near-ridge hot spot on the chemical characteristics of midocean ridge basalts (MORBs), rock samples were collected from 91 stations along the Galápagos Spreading Center (GSC) between 90° 30' W and 98° W. Basaltic glasses from these samples were analyzed for major elements by electron microprobe. Chemical trends define three types, based on K/Ti ratios: enriched MORB (E-MORB), with K/Ti ratios > 0.15 and K<sub>2</sub>O contents > 0.20 wt %; transitional MORB (T-MORB), with K/Ti ratios between 0.09 and 0.15; and normal MORB (N-MORB), with K/Ti ratios < 0.09. E-MORB rocks dominate the axial high portion of the GSC (90° 50' W to 92° 40' W), T-MORBs dominate the portion of the ridge with transitional morphology (92° 40' W to 95° 30' W), and N-MORBs dominate the axial deep re-

gion of the ridge west of 95° 30' W. MgO varies from 3 to 10 wt %, with the most fractionated E-MORBs occurring nearest the hot spot, between 91 and 92° W. In general, degree of differentiation increases with K/Ti. N-MORBs show the least differentiation, with MgO > 7.0 wt %. Relative to the other types, E-MORBs have higher K<sub>2</sub>O, TiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O, and P<sub>2</sub>O<sub>5</sub> contents and lower SiO<sub>2</sub> and FeO\* at a given MgO. In addition, E-MORBs have lower analytical totals, suggesting the likely presence of water and/or other volatiles. These chemical signatures are consistent with an interpretation that source variations, in addition to variable melting, must be involved in producing the incompatible element enrichment observed closest to the Galápagos hot spot.

## Acoustic Analysis of Objects Ensonified by a Bottlenose Dolphin (*Tursiops truncatus*) during a Cross-Modal Matching Task<sup>12</sup>

*Caroline M. DeLong*<sup>13</sup>

A bottlenose dolphin performed a matching task in which he was presented with an object (e.g., tin cup) in one modality (e.g., vision) and then asked to choose the same object from a group of three objects using another modality

(e.g., echolocation) or the same modality (e.g., vision). Object sets were presented in two cross-modal conditions (visual sample with echoic choices or echoic sample with visual choices) and two intramodal conditions (visual sample with visual choices or echoic sample with echoic choices). Acoustic measurements of the objects were made to evaluate how the dolphin used the multiple cues that were available in the echoes to perform the task. Objects were ensonified by dolphinlike clicks from several different angles and the signals were captured and digitized (objects were aspect-dependent, thus producing different echoes at different angles). The pattern of

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<sup>12</sup> Funding for the cross-modal experiment provided by Walt Disney World.

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errors made by the dolphin in the echoic-echoic condition revealed that the dolphin appeared to use the following properties of the echo signals to discriminate among objects: variations in echo highlight structure as a function of angle, variations in echo inten-

sity as a function of angle, and absolute echo intensity. The dolphin seemed to use different cues for different object sets, which suggests that he may have utilized the most optimal cue(s) available for each object set.

### Effects of Angiotensin II and Natriuretic Peptides on Prolactin and Growth Hormone Release from the Pituitary of the Tilapia, *Oreochromis mossambicus*

Steve M. Eckert<sup>14</sup>

Angiotensin II (Ang II) and natriuretic peptides (NPs) are hormones that have been shown to be an integral part of body fluid regulation in vertebrates. Not only do these hormones have direct regulatory effects, but their ability to indirectly regulate the release of other hormones is well known in higher vertebrates. Nothing, however, is known about the effect of Ang II and NPs on the release of prolactin (PRL) and growth hormone (GH) in fishes, which are hormones required to maintain hydro-mineral balance. In this study, the effects of Ang II and three NPs, atrial natriuretic peptide, C-type natriuretic peptide, and ventricular natriuretic peptide, were investigated on PRL and GH release from the pituitary in vitro. After pre-incubation in isotonic culture medium (330

mOsm) for 24 hr, whole tilapia pituitaries were incubated in 0.1 to 100 nM of each hormone, and samples were taken at various intervals. PRL and GH levels were quantified by radioimmunoassays. Ang II stimulated PRL release at 1 hr, and the effect continued through 12 hr. The effect was dose dependent. Ang II had no effect on GH release. The NPs had no effect on PRL release, but increased GH release in a dose-dependent fashion beginning at 4 hr, and remained through 48 hr. These findings of a stimulatory effect of Ang II and NPs on PRL and GH release, respectively, suggest multiple levels of control of osmoregulation in fishes and provide a basis for further studies on the hormonal control of osmoregulation not only in fishes but also for vertebrates in general.

### Electroreception in Juvenile Sandbar Sharks, *Carcharhinus plumbeus*<sup>15</sup>

Tim Fitzgerald<sup>16</sup>

Sharks possess a unique sensory system that enables them to detect the bioelectric fields emitted by prey items that are often hidden from other sensory modalities. These electric fields are usually low in both frequency (< 10 Hz) and field strength (< 500  $\mu$ V/cm). Physiological studies have shown electroreceptors

to be highly sensitive to such stimuli. This study aimed to quantify the behavioral electrosensitivity of these sharks as it relates to detecting and locating prey. Juvenile sandbar sharks, *Carcharhinus plumbeus*, were caught outside of Kāneʻohe Bay, Oʻahu, and transported to the laboratory for a series of experiments that exposed them to prey-simulating and nonprey-simulating fields. Electrical stimuli were varied in size, strength, and frequency. Sandbar sharks responded to prey-simulating DC fields at field strengths as low as a few nanovolts/cm ( $10^{-9}$  V/cm), which is in agreement with the lowest reported sensitivities for elasmobranchs. Response rates (attacks at an electric dipole) decreased as field

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strength decreased, and this trend disappeared when nonprey-simulating fields were presented. Sandbar sharks were also exposed to a variety of AC fields to determine their ability to detect frequencies other than those emitted by prey items. Sandbar sharks detected and successfully oriented to stimulus frequen-

cies as high as 10 kHz, indicating sensitivity to electrical stimuli outside the range of prey items. The results suggest that sandbar sharks are capable of detecting a broad range of electric fields and might use such information in a nonforaging capacity.

### Sea Level Change and Deforestation on the 'Ewa Plain of O'ahu during Polynesian Settlement: A Case for Coincidence

Geoffrey H. Garrison<sup>17</sup>

Ordy Pond is a shallow closed basin on O'ahu's 'Ewa Plain, containing a 9500-yr record of continuous and well-laminated sediment deposition. These sediments are almost entirely authigenic and thus primarily a function of local climate. The aim of this study has been to interpret O'ahu's Holocene climate history through geochemical analysis of both this sediment record and the modern water column. A time-series analysis of the water chemistry has shown the modern pond to be highly eutrophic and nearly entirely anoxic. Sediment chemistry indicates that the laminae are varves resulting from seasonal changes in water chemistry and authigenic productivity; carbonate laminae formed during hot, dry seasons when respiration of organic matter is highest, and organic laminae formed in the wet seasons during elevated productivity. Previous study found that the

area became deforested 930 yr B.P. and coincident with arrival of the Polynesians. Thus, those workers believed the Polynesian rat to be the most likely cause of forest decline. However, our findings indicate that the area was undergoing significant change 500+ yr before settlement. A drying trend in  $\delta^{18}\text{O}_{\text{carbonate}}$  began as early as 1540 yr B.P., followed by a shift in sediment mineralogy from calcite to aragonite at 1300 yr B.P. We believe that forest decline was actually due to a ~2 m drop in sea level that would have lowered the water table, aridified the soil, and favored the spread of grass species. The subsequent steepening of the groundwater slope and seaward shift in the meteoric/marine groundwater interface could explain the  $\delta^{18}\text{O}_{\text{carbonate}}$  freshening and the return to calcite precipitation from 1030 to 670 yr B.P.

### Effects of Alien Tree Plantations on Koa Germination and Survival<sup>18</sup>

Jennifer E. Garrison<sup>19</sup>

Foresters often plant nonnative trees to speed rehabilitation of degraded lands. However, the value of these plantations for reestablish-

ment of native plant communities remains debatable. I am investigating some of the ecological effects of mature plantations of *Casuarina equisetifolia*, *Eucalyptus robusta*, *Fraxinus uhdei*, and *Grevillea robusta* in the Nature Conservancy's Honouliuli Preserve on O'ahu. I conducted field seed-planting experiments to study the effects of plantation type, litter depth, and vegetation structure on germination and survival of four native Hawaiian forest plants. Results are presented for *Acacia koa* (germination and survival for the other three species were too low to analyze further). I

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found that plantation species significantly affected germination, growth, and survival of *A. koa*. Vegetation structure varied between the plantations, which in turn affected koa seedling survival and growth. Removal of the litter layer before planting increased time until seed germination and reduced seedling height. Therefore, if direct seeding of koa is to be undertaken, leaf litter should be left in place. It appears that *Casuarina*, *Eucalyptus*, and *Fraxinus* plantations are less likely to support

koa regeneration than *Grevillea* plantations, which had seed germination rates similar to those of native plots. However, survival of koa seedlings was higher in native stands than in any of the alien plantations. Overall, germination and survival rates were quite low in the field. Direct planting of seeds does not seem to be a productive method of increasing koa density in dry lowland forests and alien tree plantations in Hawai'i.

### Bottom-Up Influences in a Hawaiian Arthropod Community<sup>20</sup>

Daniel S. Gruner<sup>21</sup>

On young basaltic lava flows on the island of Hawai'i, nutrients severely limit primary productivity and plant diversity, but higher-level trophic effects have yet to be evaluated. This study focused on arthropods associated with the dominant species in these young successional systems, *Metrosideros polymorpha* (Myrtaceae), also the dominant tree in the Hawaiian Islands. In August and September 1998 on a 120-yr-old flow, nutrient limitation was removed by fertilization and combined with bird predator removal cages in a large-scale, well-replicated, crossed factorial design. After 1 yr, foliar nitrogen content and several measures of *M. polymorpha* growth rate were increased in fertilized relative to unfertilized plots. Arthropod densities were measured from foliage clipping samples, and herbivory

and gall densities were observed in situ over the course of the experiment. Arthropod densities, primarily detritivores, were increased in fertilized relative to unfertilized plots. In contrast, herbivory and gall (Homoptera: Psyllidae) densities were unaffected by the treatments. In both in situ and clipping samples, arthropods and their damage to plants were higher on glabrous than on pubescent tree morphotypes. The effects of top avian predators on arthropods are not yet apparent—these processes probably operate on longer temporal scales. However, top-down effects may not be strong in this system because much of the plant biomass passes directly through arthropod and microbial detritivores that are not prominent components of bird diets in the region.

### Timing of Breeding in a Hawaiian Seabird: Why Is It So Predictable?

Aaron Hebshi<sup>22</sup>

<sup>20</sup> The Hawai'i Department of Land and Natural Resources provided field access. Funding: Ecology, Evolution, and Conservation Biology Program at University of Hawai'i at Mānoa, Environmental Protection Agency, Sigma Xi, Hawai'i Audubon Society, David and Lucille Packard Foundation, and National Science Foundation DDIG program.

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Reproduction in birds is often timed to take advantage of peaks in resource abundance when the offspring is in its critical period. Seabirds have evolved two ways of timing their breeding to match peak resource (usually food) abundance: they pick up on variable environmental cues or they time their breeding to a rigid annual scale. Why should birds "choose" one strategy over the next? Specifically, why would the Wedge-tailed Shearwater, a Hawaiian seabird, choose the second strategy and begin breeding in mid-June each

year? Using data from the literature, I am testing the hypothesis that species with a large foraging range can buffer against temporary food shortages, allowing birds with large foraging ranges freedom to nest predictably—on a rigid, annual schedule. In contrast, those species with small foraging ranges face a stronger selective pressure to pick up on environmental cues sensitive to future

food availability. A comparison between foraging ranges and predictability of timing of breeding in the Hawaiian seabirds, and worldwide within the shearwater, booby, and tern families, supports this hypothesis. A computer simulation of food availability for different foraging-range sizes also shows that species with small foraging ranges must be more responsive to changes in food availability.

## Symbiont-Induced Changes in Gene Expression in the Light Organ of the Host Squid

*Euprymna scolopes*

Jennifer Kimbell<sup>23</sup>

The symbiosis between the squid *Euprymna scolopes* and the bioluminescent bacterium *Vibrio fischeri* is an exclusive partnership in which the squid host provides a nutrient-rich environment for the symbiont and the light produced by the bacteria is used by the host in antipredatory behavior. Cells of *V. fischeri* from the ambient seawater colonize the host's specialized light organ within hours of hatching. During embryogenesis of the organ, before exposure to the symbiont, a set of superficial ciliated fields develops on both sides of the organ. These structures function to direct bacteria-rich seawater toward sites of colonization. Upon colonization, the light organ undergoes a dramatic metamorphosis. At around 12 hr after infection, the bacteria provide an irreversible signal that induces the loss of the ciliated fields through apoptosis. In efforts to begin characterizing the molecular "conversations" between the host and symbiont during this signaling, I constructed

aprosymbiotic and symbiotic cDNA libraries of 12-hr juvenile light organs. I then performed subtractive hybridization between the libraries to identify populations of cDNA molecules that are preferentially expressed in the 12-hr symbiotic cDNA library. Real-time RT-PCR was used to confirm that cDNA clones of interest corresponded to mRNAs whose abundance was increased in symbiotic animals. One transcript that was upregulated in host tissue in response to bacteria was the C8 component of the proteasome. The proteasome is a multisubunit enzyme complex that is responsible for protein degradation via the ubiquitin pathway. This pathway is critical in signaling and tissue turnover, and may serve multiple functions in the early development of the host. Further investigation will reveal what precise role(s) the proteasome plays in the symbiont-induced morphogenesis of the light organ.

## Ammonia-Oxidizing Bacteria in a Hydrothermal Plume<sup>24</sup>

Phillis Lam<sup>25</sup>

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<sup>24</sup> Coauthors are James P. Cowen and Ronald D. Jones. We sincerely appreciate the conscientious assistance of Chris Alexander, Donald McGee, Rachel Shackelford, Kimberly Shaner, the crews of R/V *Thomas G. Thompson* TTN098.

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Ammonia oxidation has seldom been studied as an energy source for chemolithoautotrophy in deep-sea hydrothermal plumes. Previous studies reported anomalously high  $\text{NH}_4^+$  content in both the hydrothermal fluids (640–950 mM) and the subsequent hydrothermal plume (up to 400 nM) at the Endeavour Segment, Juan de Fuca Ridge, despite its sediment-starved nature. The net  $\text{NH}_4^+$



removal rates and turnover times were comparable with those of  $\text{CH}_4$ <sup>2</sup>; yet whether this  $\text{NH}_4^+$  was partitioned into autotrophic oxidation or assimilation was then unclear. Here we report the first direct evidence for the former process, by showing the presence of the key players, the autotrophic ammonia-oxidizing bacteria, via fluorescence in situ hybridization (FISH) with 16S rRNA-targeted oligonucleotide probes. Populations of AOB in  *$\beta$ -Proteobacteria* were found to be positively correlated with  $\text{NH}_4^+$  concen-

trations and apparent autotrophic removal rates. They comprised 1.6–32.5% of the total microbial community, whereas the upper end lay close to that in sewage treatment plants. Their abundance was similar to that of Type I methane-oxidizing bacteria, and their biomass could be as much as >300% of measured surface-derived organic carbon flux to this depth. These findings imply that ammonia oxidation could be a significant in situ organic carbon production process in this deep-sea hydrothermal plume.

### Localizing Dolphin Acoustic Signals Using a Three-Hydrophone Towed Array: Preliminary Findings

Marc O. Lammers<sup>26</sup>

Studies of animal behavior depend upon a researcher's ability to make accurate observations of the subject under investigation. This can be a considerable challenge for those not well adapted to their study animal's environment and sensory *umwelt*. A notable example is the investigation of underwater bioacoustic behavior among dolphins. Researchers interested in the use of sound as a communication tool by dolphins have traditionally faced two major challenges: (1) The inability to localize the source of a sound underwater and (2) a lack of hearing sensitivity at the high-frequency bands associated with dolphin signaling. It is not surprising that much remains uncertain about the propagation characteristics of many sounds and about how dolphins use specific signals to communicate. To overcome these limitations, a recording system was

developed to localize broadband dolphin signals using a towed three-hydrophone array. This system uses a high-speed analog to digital converter to simultaneously sample three hydrophones spaced 12 m apart towed behind a boat. Using cross-correlation to establish a signal's time of arrival difference at each channel, the position of phonating animals can be geometrically inferred. Initial findings reveal that among spinner dolphins (*Stenella longirostris*) specific signals are sometimes shared between individuals. Evidence is also being found to suggest that dolphins, at times, synchronize their signaling behavior. Although still preliminary, such results indicate that the array system does have the potential to contribute significantly to our understanding of the communication behavior of free-ranging dolphins.

### Resurrection and RAPDs: A New Look at the Endemic *Sophora chrysophylla* (Fabaceae)

Shelly J. Lammers<sup>27</sup>

*Sophora chrysophylla* (māmane) is a Hawaiian endemic species in the pea (Fabaceae) family.

This species is found in dry and mesic forests on all of the major Hawaiian islands. Māmane shows a wide diversity of physical attributes including variation in leaf type, growth form, flower and seed pod shape, leaf pubescence, and seed color. Although only one species is currently recognized in Hawai'i, several different taxa have been recognized historically. A preliminary study of the genetic diversity of

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māmane was conducted using RAPD genetic analysis. Individuals from the islands of O'ahu, Lāna'i, Maui, and two widely spaced populations on Hawai'i (Mauna Kea and Hawai'i Volcanoes National Park) were examined. Twenty four primers were screened for amplification; of these 20 produced well-defined bands that could be identified as discreet loci. A total of 173 loci was scored. Of these, 70 (40%) showed no variation between islands, 73 (42%) were unique to a particular island,

and 30 (17%) were shared between multiple (but not all) islands. An additional aspect of the study involves the examination of a māmane with a unifoliolate leaf form. This form is presumed to be extinct in the wild, but seeds have been preserved at Bishop Museum on an 88-yr-old herbarium specimen. Germination is currently being attempted using sterile tissue culture techniques in conjunction with Lyon Arboretum for both genetic analysis and conservation possibilities.

### Spawning Dynamics of Hawaiian Sanddivers *Limnichthys donaldsoni* and *Crystallodytes cookei* (Teleostei: Creediidae)

Ross Langston<sup>28</sup>

Lifetime fecundity in pelagic-spawning fishes is a product of batch size, spawning frequency, and adult life span. Relative to larger species, lifetime fecundity of small reef fishes may be constrained by their presumptive short life spans and small batch sizes. Small species may compensate for these factors either by extending their spawning season or by increasing spawning frequency within the season. In this study I examined spawning seasonality and periodicity of two species of small (<60 mm), protandrous, sand-dwelling fishes common to Hawaiian waters, *Limnichthys donaldsoni* and *Crystallodytes cookei*. Specimens were collected weekly between June 1999 and January 2001. Relative maturity

of females was assessed by dividing gonad weight by somatic weight (G/S). Based on the G/S index, *L. donaldsoni* and *C. cookei* both have a long reproductive season; peak G/S values occur in March through July followed by a decrease in the late summer months of September through October. Slight secondary peaks are visible for both species in November–December. Both species show three distinct peaks of gonad development over the lunar month; largest G/S values occur on the new moon and first quarter followed by a less distinct peak on the last quarter. Despite their small size, *C. cookei* and *L. donaldsoni* have spawning cycles similar to those of larger-bodied Hawaiian reef fishes.

### Hox Gene Expression during Development of the Sepiolid Squid *Euprymna scolopes*<sup>29</sup>

Patricia N. K. L. Lee<sup>30</sup>

Cephalopods represent a highly derived group within the mollusks. They have evolved ex-

tensive alterations in the basic molluscan body plan, including reduction/loss of the shell, novel recruitment of the mantle for locomotion, and modification of the foot into a crown of prehensile arms around the head. The most striking modifications are those involving the anterior–posterior (AP) and dorsal–ventral (DV) axes. In cephalopods, the visceral mass has undergone extensive elongation along the DV axis, and the body along the AP axis has been greatly compressed. As a result, the functional AP axis

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corresponds to the embryonic DV axis. To understand how morphological changes relative to the body axes have arisen in cephalopods, we examined *Hox* genes in the sepiolid squid *Euprymna scolopes*. *Hox* genes are expressed along the AP axis in nested domains in bilaterians. As a result, they can be used as highly conserved molecular markers specific for the AP body axis. Using RACE-PCR, we

have cloned seven *Hox* orthologues from *E. scolopes* and used these clones as probes for in situ hybridizations to examine their patterns of expression during development. Preliminary results for three *Hox* genes suggest that the nested expression pattern may be conserved in some regions along the AP axis, but not others.

### Effects of Blood Withdrawal on Plasma Prolactin, Growth Hormone, and Drinking in the Tilapia (*Oreochromis mossambicus*)

Thomas A. Leedom<sup>31</sup>

The effects of repeated blood withdrawal on plasma levels of prolactin (PRL) and growth hormone (GH) and drinking rate were examined in the euryhaline tilapia. Blood (350  $\mu$ l/100 g body weight or 5% of estimated blood volume) was taken at 0, 1, 4, 8, 24, 48, 76, and 120 hr. Blood withdrawal in tilapia acclimated to freshwater (FW) resulted in a marked increase in plasma levels of PRL in association with a decrease in plasma osmolality. A slight increase in GH was also observed. When blood was withdrawn from the fish in seawater (SW), a significant increase in plasma GH was observed accompanied by a marked increase in plasma osmolality. No effect of blood withdrawal was seen on plasma PRL levels, which were kept at lower concentrations than freshwater levels. In con-

trast, there was no change in plasma PRL and GH levels after blood withdrawal in fish acclimated to 30% SW. Blood withdrawal resulted in a significant reduction in hematocrit values in all treatments, suggesting hemodilution. In a separate experiment, a single blood withdrawal (1.4 ml/100 g) stimulated drinking in tilapia acclimated to FW, 30% SW, and SW. Plasma PRL was also elevated after blood withdrawal in the fish acclimated to FW and 30% SW; however, no effect was seen in SW. These results suggest that increased PRL concentration in the fish in FW is correlated to hemodilution and a decrease in plasma osmolality. GH, on the other hand, is elevated in response to hemodilution and increased plasma osmolality, indicating an important role for GH in SW adaptation.

### Role of Food in Community Structure of Reef Fishes

Ken Longenecker<sup>32</sup>

Reef fish diversity models, unlike more general diversity gradient hypotheses, assume that food does not influence community structure. This assumption appears to be an artifact of the low taxonomic resolution typi-

cally used in studies of fish diets. I performed detailed dietary analyses on eight small, cryptic, diurnal fish species from the spur and groove outside Kāne'ohe Bay, O'ahu, Hawai'i, to test whether dietary specialization may allow the high species richness observed in reef fishes. The majority of the diet of each fish species was a unique combination of  $3.25 \pm 1.75$  (SD) benthic prey species having traits that allow local long-term persistence. Mean dietary overlap (17.9%) among these fishes is similar to overlap among organisms

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from communities structured by fine-scale food resource partitioning. Regression analysis, using data from studies with high taxonomic resolution, indicated a significant decrease in dietary overlap among fishes as latitude decreases. These results, along with an increase in prey diversity toward the Tropics, are consistent with diversity gradient hypotheses and suggest that food specialization may allow the local coexistence of many fish species on coral reefs. I used multiple re-

gression to evaluate whether species evenness of reef fishes is influenced by prey availability. Although some relationships were complex, the densities of five of six fish species were positively related to densities of important prey. Combined, my results indicate that food choice and availability influence both components of diversity (richness and evenness, respectively) in reef fishes and suggest that reef fish communities may be structured in the same manner as other tropical communities.

### Search for New Antitumor Drugs from Marine Cyanobacteria

Hendrik Luesch<sup>33</sup>

Cyanobacteria are a prolific source of secondary metabolites exhibiting a broad spectrum of bioactivities. Many of these compounds are cytotoxic and potentially useful as chemotherapeutic agents if selective against tumor cells. Our search for compounds with selective cytotoxicity led to the investigation of particular strains of the marine cyanobacteria *Lyngbya majuscula* and *Symploca hydroides* collected at Guam, Palau, and Hawai'i. Several novel and remarkably potent cytotoxins with unusual structural features were isolated from extracts of these organisms using bioassay-guided solvent partition followed by normal-phase chromatography and reversed-phase chromatographic steps. Their structures were determined by extensive application of NMR spectroscopy, analysis of degradation products, and other analytical methods. The new cytotoxins are of mixed peptide-polyketide biogenesis and have been termed lyngbyastatins, symplostatisins, lyngbyabellins, and apra-

toxins. Some of them structurally resemble compounds previously isolated in low yields from marine invertebrates. The isolation of dolastatins, including the human clinical trial compound dolastatin 10, and the discovery of structural analogues support the proposal that many compounds originally isolated from the sea hare *Dolabella auricularia* are of cyanobacterial, dietary origin. The identification of the true source of these metabolites potentially allows the study of their biosynthesis and the heterologous expression of their biosynthetic genes. Toward the goal to isolate and characterize the biosynthetic gene clusters responsible for the formation of the cytotoxins, genomic DNA was isolated from the producing cyanobacteria. Conserved regions of genes encoding nonribosomal peptide synthetases and polyketide synthases have been targeted by PCR. The resulting specific PCR products are being used as probes to screen the genomic DNA/cosmid library.

### Rats Versus Bugs: Importance of Seed Predator Biology for Plants

Timothy D. Male<sup>34</sup>

Pre- and postdispersal seed predators have an enormous potential to affect plant recruit-

ment because they consume 60–100% of seeds of many tropical plant species, and there is broad consensus that such predation shifts recruitment patterns away from those that would be expected based on seed distribution alone. However, there has been little systematic work to document how the type of seed predator shapes recruitment. I set out to survey seed predation in an Australian sub-

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tropical forest to identify whether mammalian and invertebrate seed predators showed different responses to the dispersion of seeds of six canopy tree species. I found substantial mortality of all seed species during the study, with only 22% of seeds remaining intact by the last seed survey conducted. Three species suffered substantial losses from mammalian seed predation ranging from 52 to 82%, and the other three species suffered losses from invertebrate predators ranging from 39 to

89%. Seed species attacked by invertebrates had significantly higher seed survival at locations away from fruiting trees; species attacked by mammals showed no pattern between survival and distance from fruiting trees or a decrease in survival with distance. These results suggest that it is essential to identify the type of seed predators responsible for seed mortality before making predictions about spatial patterns of plant recruitment and forest dynamics.

### Where Do Arrow Worms Belong? A Phylogenetic Study of a Marine Chaetognath, *Fasciflagitta enflatta*

David Matus<sup>35</sup>

Chaetognaths (also known as arrow worms) have at different times been placed phylogenetically as protostomes along with brachiopods, spiders, mollusks, and nematodes, or as a basal deuterostome based on morphological and embryological characters. They possess a tripartite body organization composed of a head, midbody, and a posterior transverse septum as well as a pseudocoelomate-like musculature composed of longitudinal muscles and a thick cuticle. Embryologically, arrow worms are characterized by enterocoely and radial cleavage. Recent molecular data based on 18S RNA sequences suggest that chaetognaths belong in the Ecdysozoa, a major

protostome bilaterian clade, clustered most strongly with nematodes. Due to the inherent problems with 18S data, we are investigating protein-coding genes in structural (e.g., actin, myosin,  $\beta$ -catenin) and developmental regulatory gene families such as *Hox* and *ParaHox* genes. Through sequence analysis and expression studies we can more accurately solidify chaetognaths' place in the Ecdysozoa. Partial sequences have been determined via polymerase chain reaction (PCR) from genomic DNA of several *Hox* and *ParaHox* genes, including *ultrabithorax*, *labial*, *abdominal b*, *sex-combs reduced*, *Hox 3*, *xlox*, and *Pax2* as well as a 1-kb fragment of an *actin* gene.

### Mating System Parameters and Viable Population Sizes

Andrew McClung<sup>36</sup>

The Laysan finch (*Telespyza cantans*) is an endangered passerine bird, endemic to the

Northwest Hawaiian Islands, whose mating system has long been considered monogamous. However, these birds are sexually dimorphic in both size and plumage coloration, suggesting some frequency of polygyny or extra-pair mating. In fact a polygynous male, along with two females and their nests, was observed in 1999, among one of the translocated populations at Pearl and Hermes Reef (PHR). After extracting DNA from the feathers of more than 200 PHR finches representing about 35 families, I amplified and

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sized alleles at eight microsatellite loci. The resulting genotypes permit comparison of behaviorally assigned parentage to genetic assignments and thus estimation of the frequency of extra-pair matings. That informa-

tion, in turn, leads to more detailed estimates of effective population size and extinction probabilities among the translocated populations.

### **Are Hawai'i's Marine Reserves Large Enough? The Waikiki Marine Life Conservation District as a Case in Point**

*Carl Meyer*<sup>37</sup>

"No fishing" marine reserves (MR) are being increasingly suggested as useful tools for mitigating the negative effects of human activity on coral reefs. To date, the choice of locations and boundaries for MRs has been opportunistic and based primarily on anthropocentric concerns. Unfortunately, designing MRs in this way, rather than around the biology of the organisms that they are intended to protect, may limit the effectiveness of these areas. For example, many of the anticipated benefits of MRs are dependent upon these areas being large enough to effectively protect "resident" populations of fishes and other exploited organisms. To achieve this aim, MRs must be large enough and contain sufficient critical habitat to ensure that most resident individuals do not range beyond the boundaries into fished areas. The aim of this study

was to determine whether an existing MR (Waikiki Marine Life Conservation District [MLCD]) is large enough and contains sufficient suitable habitat to contain the home ranges of three species of coral reef fishes that are representatives of a wide range of feeding and vagility guilds. To address this question, fish movement patterns, habitat use, and home range sizes in the Waikiki MLCD are being quantified using acoustic telemetry (tracking) and conventional identification tags. Results indicate that the Waikiki MLCD is only large enough to protect a resident population of one of the three species investigated (*Naso unicornis*). The other two species investigated (*Mulloides flavolineatus* and *Caranx melampygus*) frequently range beyond the reserve boundaries in the course of their daily movements.

### **Use of Dried Tissues and Molluscan Shells for Molecular Systematics of Rare Mollusks**<sup>38</sup>

*Fabio Moretzsohn*<sup>39</sup>

When fresh or preserved specimens for molecular systematics study are difficult to obtain, the option of using museum specimens may

be a viable alternative. One caveat is that the researcher cannot be certain of how quickly the tissue desiccated or how the specimen was maintained over the years. Therefore, as with other sources of aDNA (ancient DNA), there is a risk of extraneous DNA and other contaminants that can inhibit PCR. Despite these potential problems, it is possible to recover PCR-amplifiable DNA that can be useful in molecular systematics. In a study of the *Cribrarula cribraria* species complex (Gastropoda: Cypraeidae), mostly museum specimens were

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used. Most specimens with dried tissue yielded the radula (or parts of it), and the DNA obtained from such tissues was usually degraded but amplifiable in a few cases (about 20% of samples). The calcareous molluscan shell was also investigated as a potential source of DNA. Appropriate care was taken to avoid contamination: solutions were autoclaved, shells and tools were treated with undiluted bleach, soaked in a strong solution of NaOH, rinsed in distilled water, and then exposed to UV light to remove any surface-clinging DNA. In all instances, spectrophotometer readings at 260 nm detected a low DNA yield, but DNA was not visible in agarose

minigels. One sample was eventually amplified and sequenced (313bp mtDNA), matching the sequence obtained from a fresh specimen, thus suggesting that authentic DNA was recovered. Although this result is not surprising, the lack of similar reports in the literature is interesting. If primers for shorter fragments and more accurate techniques to remove PCR-inhibitors are used, a larger proportion of samples may become viable. Though it is laborious and expensive to make shell and dried tissue samples work, the technique may be justifiable for studies of rare or extinct species.

### Effects of Forest Species Composition on Rainfall Interception in the Honouliuli Preserve Watershed

Teresa Restom<sup>40</sup>

The objectives of this study were to estimate the effect of species composition on the water cycle of forest ecosystems and the potential of stands dominated by each of three species to recharge groundwater. Components of the water cycle (canopy interception, transpiration, and soil moisture) have been studied in stands dominated by *Casuarina equisetifolia*, *Eucalyptus robusta*, and *Fraxinus uhdei*. Groundwater recharge is estimated as the difference between rainfall and evaporation (canopy interception + transpiration). Data on canopy interception components, throughfall, and stemflow have shown that species characteristics influence the amount of evaporation per rainfall event. *Fraxinus uhdei* pre-

sented higher stemflow rates (average of 1.2 liters/tree/day) than *E. robusta* (0.6 liters/tree/day) or *C. equisetifolia* (0.4 liters/tree/day). Throughfall was significantly different only for one stand of *F. uhdei* (79% of rainfall), which was higher than that of the other two species (57% of rainfall) in the northern part of the preserve. These results suggest that the canopy of *F. uhdei* may intercept less rainfall than those of the other two species, allowing higher groundwater recharges. This study demonstrated that species composition may affect the water cycle in forests and thus is a factor that should be carefully taken into account when planning watershed restoration programs.

### Hypothalamic Regulation of Growth Hormone Cell Function in the Tilapia, *Oreochromis mossambicus*

Larry G. Riley<sup>41</sup>

In teleosts, growth hormone (GH) is involved in the regulation of several physiological

processes. These include growth, osmoregulation, metabolism, reproduction, and development. These processes constantly influence each other within the animal, making our understanding of regulatory mechanisms of GH release from the pituitary difficult to investigate. In teleosts, several factors have been implicated in stimulating GH release, such as growth hormone releasing factor (GRF),

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gonadotropin-releasing hormone (GnRH), and pituitary adenylate cyclase-activating polypeptide (PACAP). Recently, a newly isolated peptide from the rat stomach, ghrelin, was identified and shown to stimulate GH release in the rat. This study was conducted to examine the effects of mammalian ghrelin, GRF, and PACAP on GH release from the tilapia pituitary in vitro. Rat ghrelin and human PACAP significantly stimulated GH release dose dependently at concentrations of

1–300 nM. The effect was significant as early as 4 hr after start of incubation and lasted for 24 hr. Human GRF significantly stimulated GH release also but was less effective than ghrelin and PACAP. NO effect of ghrelin, PACAP, and GRF was seen on gene expression of GH after 24 hr of incubation. These results indicate for the first time that ghrelin stimulated GH release in teleosts and also that the effect of ghrelin is equipotent with PACAP and more potent than GRF.

### Aspects of the Evolution of Hawaiian Endemic Succineid Land Snails

Rebecca J. Rundell<sup>42</sup>

The Hawaiian land snail fauna is incredibly speciose and ecologically diverse. There are 763 nomenclaturally valid species, and they inhabit virtually every ecological zone in the Hawaiian Islands. The Hawaiian endemic species of the worldwide family Succineidae illustrate this diversity. There are 41 species, and these inhabit a wide variety of ecological zones, including montane rainforest and coastal dunelands. A sequencing study of the Hawaiian endemic succineids was undertaken to investigate the evolutionary relationships of these species. A 680-base pair region of the mitochondrial COI gene was sequenced

for the following species: *Catinella explanata* (Kaua'i), *Catinella rotundata* (O'ahu), *Catinella baldwini* (Maui), *Succinea canella* (Moloka'i), and *Succinea rubella* (Lāna'i). A neighbor-joining tree using a Kimura 2 parameter model was produced, using the Hawaiian achatinellid *Auriculella ambusta* as an outgroup. *Auriculella ambusta* differs genetically from the ingroup by 30%. Pairwise inter-specific genetic distance within the ingroup ranges from 4.6 to 16.6%. The average genetic distance is 13.6%. Groupings within the tree do not follow the traditional taxonomic groupings of *Catinella* and *Succinea*.

### Osmoreception: The Essential Modality for a Euryhaline Life

André P. Seale<sup>43</sup>

In the tilapia (*Oreochromis mossambicus*), as in many euryhaline teleosts, prolactin (PRL) plays a central role in freshwater adaptation, acting on osmoregulatory surfaces to reduce ion and water permeability and increase solute retention. Consistent with these actions, PRL

release is stimulated as extracellular osmolality is reduced both in vitro and in vivo. The ability of osmolality to directly control the osmoregulatory output of the PRL cell provides an excellent model to elucidate the mechanisms by which an osmotic signal is transduced in an osmoreceptive cell. Moreover, tilapia PRL cells are arranged into a nearly homogeneous tissue within the *rostral pars distalis* of the pituitary gland and therefore can be easily separated for in vitro studies. In the tilapia, hypototically induced PRL release in vitro is dependent on extracellular calcium and is tightly correlated with an in-

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crease in cell size and a rise in intracellular free calcium. We hypothesize that reduced osmolality elicits an increase in PRL release through the opening of stretch-gated channels that are tied to an increase in cell size. We investigated the effects of ouabain and nystatin, known to elicit cell swelling in the absence of an osmotic gradient, on PRL release. Also, we assessed the presence of stretch-activated cation channels in the tilapia PRL cells using gadolinium ( $Gd^{3+}$ )

and chlorpromazine. Ouabain, nystatin, and chlorpromazine treatments significantly increased PRL release within 1 hr of static incubation. PRL was inhibited under hypotonic conditions by 18 hr of static incubation with  $Gd^{3+}$  (100 and 1000  $\mu M$ ). These results support the hypothesis that an increase in cell size is a critical step in the transduction of an osmotic signal into PRL release, suggesting the involvement of stretch-activated ion channels.

### **Ethical Issues Surrounding Somatic Cell Gene Therapy (SCGT)<sup>44</sup>**

*Catherine J. Simonovich<sup>45</sup>*

Somatic cell gene therapy (SCGT) comprises a number of potential medical treatments that are currently the subject of intense interest in the biomedical research community. SCGT will probably be available clinically in the future, and its impact will be felt worldwide with potential negative consequences for humanity if ethical issues are not adequately addressed. This presentation provides in-

formation about ethical issues surrounding SCGT, the scientific basis of SCGT, and the regulations and history of SCGT research. Concerns about the research methods and practices of SCGT and ethical issues regarding other potential societal consequences are discussed. Specifically, the issue of treatment versus enhancement in the potential uses of SCGT is addressed.

### **Nearshore Currents in Hanauma Bay, O'ahu, Hawai'i, and Their Possible Relationship to Larval Ecology**

*Amber Whittle<sup>46</sup>*

Both nearshore and offshore larval ecology has often been viewed as a "black box." In the past, scientists have hypothesized that fish larvae are passive entities carried by currents, but recent evidence has shown that fish larvae may have the ability to actively orient and swim against the current. Other studies have shown that larvae may be retained in their natal habitats. I am currently studying the

larval ecology of fishes in Hanauma Bay, a Marine Life Conservation District on O'ahu, Hawai'i. I undertook, along with 12 volunteers, the mapping of the nearshore currents in the bay. I hypothesized that more larvae would be found in the retention areas of the bay (the NNW corner) than in the other areas, including the outer portion. I combined drogue and light trap studies. The drogue study used volunteers at four stations recording time and compass headings of six individually marked drogues in the bay. This study was conducted on a calm, incoming tide on 10 November 2000. The mapped nearshore currents showed a definite retention of all drogues in the NW portion of the bay (in Witches' Brew or nearer shore). Over the past year, I have, twice monthly, placed two

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to three light traps in fixed areas in the bay: in the sandy center of the bay near the outer boundary, in the sandy outer boundary of Witches' Brew, in the coral NNW nearshore area, and in the inner rubble area of Witches' Brew. So far, my hypothesis has been proven

false: I have found an almost equal amount of fish larvae in the inner Witches' Brew and the outermost positions, and relatively no larvae in the outer Witches' Brew and inner NNW positions. I have also found a similar distribution of neotenic *Schindleria* fishes.

### Asymmetric Impacts of Mycorrhizae and Fire on Competitive Interactions among Grasses

Mindy Wilkinson<sup>47</sup>

Fire and arbuscular mycorrhizal (AM) fungi can potentially affect survival and competitive interactions between invasive and native plants. In this study greenhouse experiments were used to test the effects of AM fungi and drought on intra- and interspecific competition among two invasive bunchgrasses (*Hyparrhenia rufa* and *Melinis repens*) and an indigenous bunchgrass (*Heteropogon contortus*) that co-occur in an arid Hawaiian grassland. Survival, aboveground biomass, and recruitment of these species were also monitored in response to prescribed fires at two sites in Hawai'i Volcanoes National Park. At the first site, *Melinis* mortality was increased by fire, but the mortality of burned *Hyparrhenia* and *Heteropogon* was not different from that of

unburned controls. One year following fire the density of *Melinis* individuals was reduced, but *Heteropogon* and *Hyparrhenia* densities were not affected. At the second site, the fire was more intense and all species experienced high and similar mortality rates. After 1 yr *Heteropogon* densities declined more than the densities of *Hyparrhenia* and *Melinis*. In the greenhouse *Heteropogon* produced less biomass in interspecific competition than in intraspecific competition under all treatments; however, the magnitude of the difference between *Heteropogon* and its competitors was reduced 95% in the AM fungal treatment. Under some conditions, fire appears to selectively reduce populations of one of the invaders (*Melinis*), but AM fungi mediate competition between the native *Heteropogon* and the invasive species by differentially increasing the growth of the native, resulting in reduced competitive impact of the invaders.

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