

Samuel E. Kahng · Richard W. Grigg

## Impact of an alien octocoral, *Carijoa riisei*, on black corals in Hawaii

Received: 17 June 2004 / Accepted: 16 June 2005 / Published online: 7 September 2005  
© Springer-Verlag 2005

**Abstract** In 2001 *Carijoa riisei*, an octocoral native to the tropical Western Atlantic, was discovered overgrowing black corals in the Au'au Channel in Hawaii. In this paper data from a 2001 survey are reanalyzed and combined with new data from 2003 and 2004 to assess the ecological impact in greater detail. *C. riisei* differentially affected reproductively mature black coral colonies with maximum impact between 80 and 105 m. The pattern of *C. riisei* overgrowth on black corals and *C. riisei* on the substrata appears to be bounded by high irradiance in shallow water and cold temperature in deep water. Evidence suggests that the *C. riisei* settlement on black corals is facilitated by other epifauna. Once established, *C. riisei* spreads vegetatively and smothers the coral. The success of the *C. riisei* invasion appears to be unaided by anthropogenic disturbance and is at least partially attributable to Hawaii's depauperate shallow-water (< 100 m) octocoral fauna.

**Keywords** Introduced species · Octocoral ecology · Black coral · *Carijoa riisei* · *Antipathes dichotoma* · *Antipathes grandis*

### Introduction

*Carijoa riisei* (Duchassaing and Michelotti 1860) is a shallow-water octocoral (Order Alcyonacea, Family Clavulariidae) that is native to the tropical Western Atlantic where it commonly occurs from Florida to Brazil and throughout the Caribbean (Bayer 1961). *C. riisei* was first found in Hawaii in 1972 in the fouling

community in Pearl Harbor (Evans et al. 1974).<sup>1</sup> Since its initial discovery *C. riisei* has spread throughout the main Hawaiian Islands (Devaney and Eldredge 1977; Thomas 1979; Coles and Eldredge 2002).

In 2001, a deep water survey of the Maui Black Coral Beds in the Au'au Channel between the islands of Maui and Lanai (Fig. 1) showed that a significant number of dead black coral colonies were overgrown with *C. riisei* at depths deeper than 75 m (Fig. 2) (Grigg 2003, 2004). In some areas up to 90% of the black coral colonies were dead and completely overgrown (Grigg 2003). *C. riisei* lacks zooxanthellae and is skiophilous (shade loving). It has been described to be a fast growing, shallow-water species in its native habitat (Bayer 1961; Rees 1969). In Hawaii it was previously thought to be a relatively benign introduction occupying an underutilized habitat (Coles and Eldredge 2002). The results from the 2001 survey and the new data reported in this paper demonstrate this is no longer the case.

Hawaiian black corals *Antipathes dichotoma* and *Antipathes grandis* are commercially valuable species used for the manufacture of precious coral jewelry (Grigg 1976). Since 1958, there has been an active fishery that has been successfully managed (Grigg 2001). Black coral is the official gemstone for the state of Hawaii and supports a \$30 million statewide precious coral industry (Grigg 2004). Both species occur at depths between 30 and 120 m in Hawaii (Grigg 1976). *A. dichotoma* grows vertically at a rate of about 6 cm per year and takes approximately 12 years to reach sexual maturity (Grigg 1976).

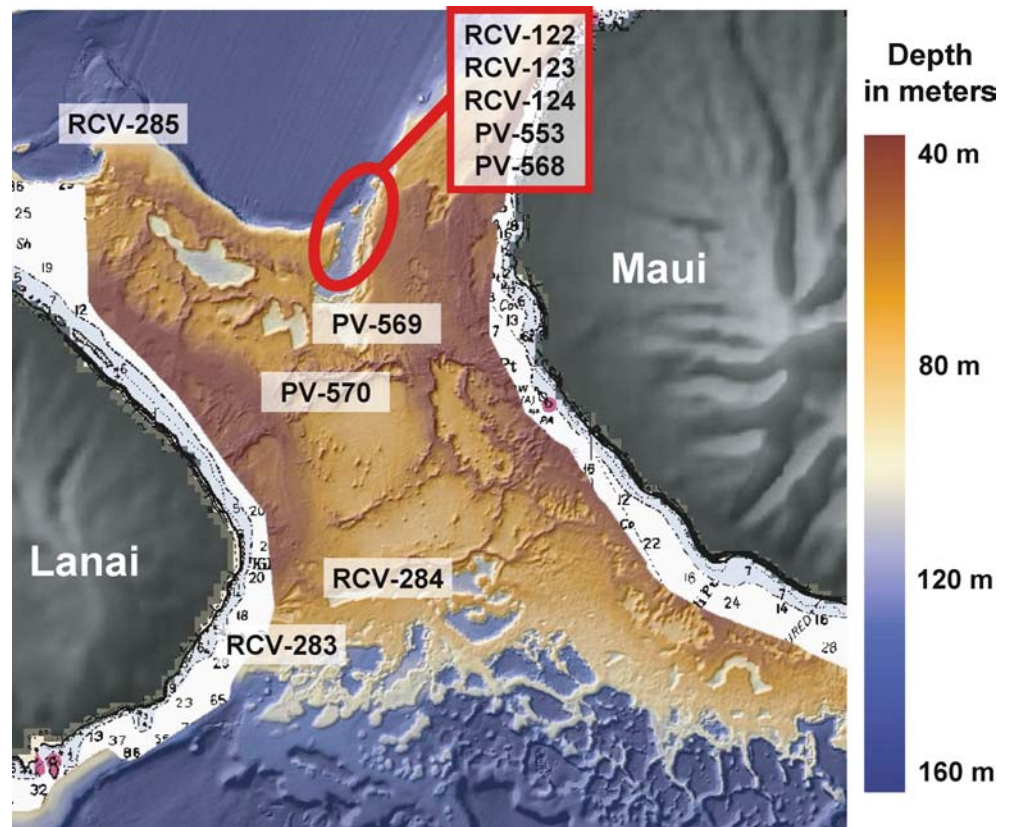
The history of introduced marine species in Hawaii dates back to 1866 when an attempt to culture eastern oysters *Crassostrea virginica* was made in Pearl Harbor (Coles et al. 1999). From that time maritime vectors, the aquaculture industry, and the aquarium trade have been implicated in the introduction (both intentional and unintentional) of over 343 nonindigenous marine species in Hawaii (Coles et al. 1999; Eldredge and Carlton

Communicated by Biological Editor H. R. Lasker

S. E. Kahng (✉) · R. W. Grigg  
Department of Oceanography, University of Hawaii, 1000 Pope  
Road, Honolulu, HI 96822, USA  
Tel.: +1-808-956-5961  
Fax: +1-808-956-9516  
E-mail: kahng@hawaii.edu  
E-mail: rgrigg@soest.hawaii.edu

<sup>1</sup>Formerly known as *Telesto riisei*

**Fig. 1** Map showing the location of the *Pisces V* submersible dives and RCV remotely operated vehicle deployments in the Au'au Channel between the islands of Maui and Lanai in the Hawaiian Archipelago. Red circle indicates the black coral bed in the Keyhole Pinnacle area surveyed in 2001, 2003, and 2004. Detailed bathymetry is from multibeam surveys by the US Geological Survey Pacific Seafloor Mapping Project and is color coded for depths 40 m and deeper. Numbers on the underlying nautical chart are in fathoms



2002). Of these, 287 species are nonindigenous marine invertebrates with most occurring within the major harbors and a few proliferating on adjacent coral reefs (Eldredge and Carlton 2002). *C. riisei* is the only confirmed nonindigenous coral established in Hawaii (Coles, personal communication).

The accidental introduction of *C. riisei* in Hawaii represents a significant ecological event since only a few shallow-water (< 100 m) octocoral species are native to Hawaii: *Sarcothelia edmonsoni* (Family Xenidae), *Sinularia densa* and *S. molokaiensis* (Family Alcyoniidae); and *Acabaria bicolor* (Family Melithaeidae) (Grigg and Bayer 1976; Devaney and Eldredge 1977; Hoover 1998; Fenner 2005). *S. edmonsoni* is zooxanthellate, widely distributed in shallow water (Davis 1977; Devaney and Eldredge 1977). *Sinularia densa* and *S. molokaiensis* are also zooxanthellate but less common (Fabricius and Alderslade 2001; Fenner 2005). *A. bicolor* is azooxanthellate, occurs to depths greater than 400 m (Devaney and Eldredge 1977; Hoover 1998), and may have originated as a deep water species (Grigg and Bayer 1976).

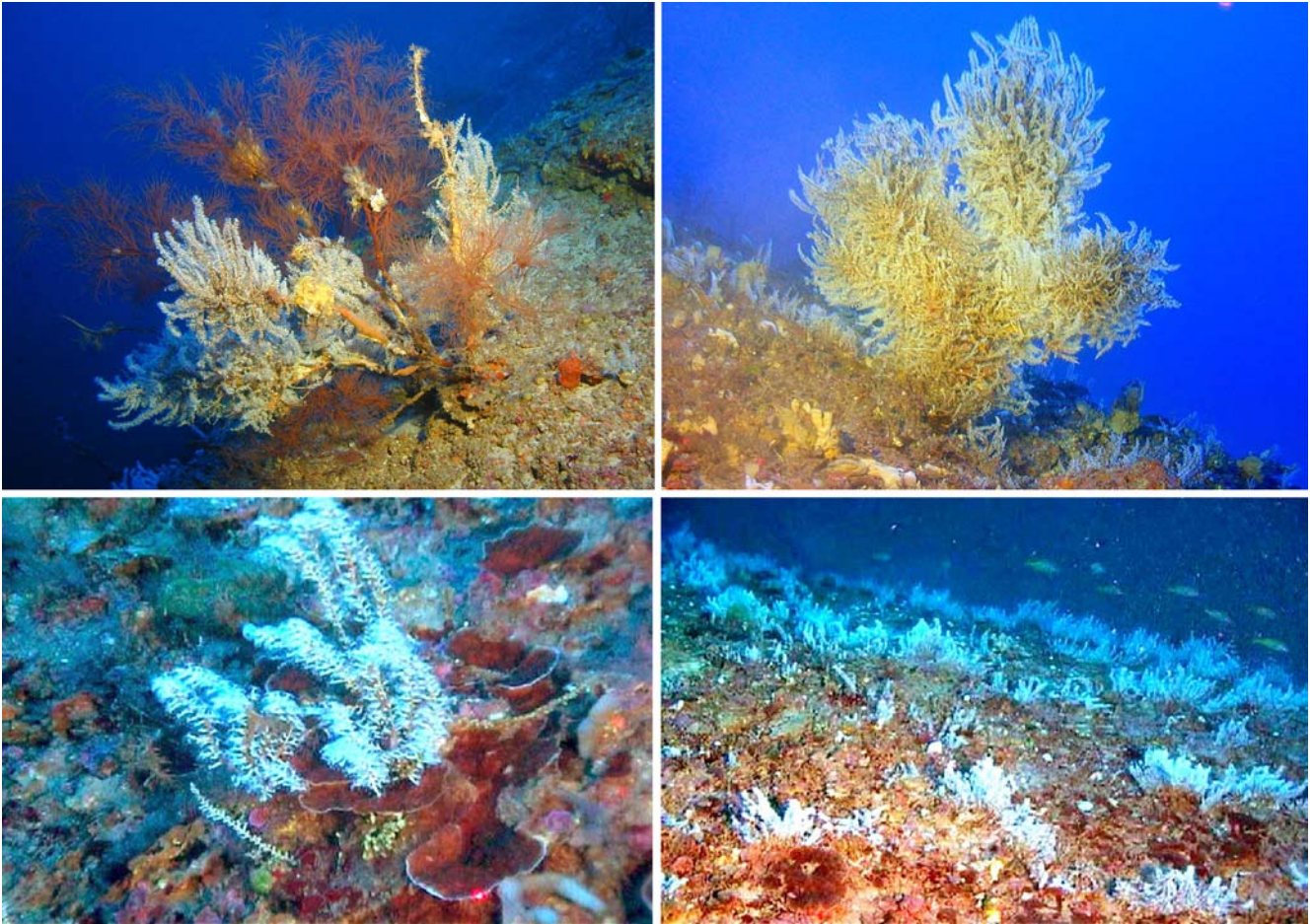
In terms of biodiversity, the number of shallow-water (< 100 m) octocoral species in Hawaii is anomalously low compared to the Scleractinian coral species. Hawaii has roughly 10% the number of shallow-water Scleractinian species occurring in the central Indo-Pacific (Veron 1995). In comparison, Hawaii has approximately 0.5% the number of shallow-water octocoral species occurring in the central Indo-Pacific (Spalding et al.

2001). In many coral reef ecosystems, particularly in the Caribbean Sea and the Indo-West Pacific, octocorals form a major and sometimes dominant faunistic component (Bayer 1961; Dinesen 1983; Spalding et al. 2001).

*C. riisei* is commonly observed on hard substrata in shaded habitat with moderate current flow. In the clear oceanic water surrounding Hawaii, *C. riisei* is restricted to shaded habitat at depths shallower than 40 m (personal observations). In the Au'au Channel, *C. riisei* was first reported in shallow water by sport divers in the early 1990s. Observations in the Au'au Channel in 2001 suggest that *C. riisei* may be causing large-scale mortality of black corals in the depth range of 75–110 m (Grigg 2003, 2004). No large-scale mortality of black coral colonies has been observed previously from any causal factor other than harvesting through 40 years of continuous black coral research and commercial fishing activity (Grigg 2001).

The purpose of this study is to quantify the present ecological impact of *C. riisei* on black corals and identify patterns of distribution and abundance. This analysis is one component of an ongoing study of the biology and ecology of *C. riisei* in Hawaii. In 2001, video data of the Au'au Channel as reported in Grigg (2004) were collected to quantify the ecological impact of *C. riisei* and its depth distribution relative to black corals. In 2003 and 2004, submersible dives and remotely operated vehicle (ROV) deployments covering part of the same area as the 2001 survey were conducted to determine if





**Fig. 2** Upper left: a black coral (*A. dichotoma*) colony with partial *C. riisei* overgrowth at 90 m. Upper right: a recently dead black coral completely smothered by *C. riisei* at 90 m. Lower left: *C. riisei* overgrowing plate corals (*Leptoseris* sp.) at 70 m. Lower right: *C. riisei* overgrowing open substrata at 70 m. Photographs (upper row) and video frame grabs (lower row) courtesy of HURL

*C. riisei* was smothering and killing black coral colonies and whether its impact was increasing over time. Previously unexplored areas of the Au'au Channel were also surveyed to assess the geographic spread of *C. riisei* at depth. For the present study a subset of the previously reported 2001 video data, previously unreported 2001 video data, and new video data from 2003 and 2004 were analyzed in greater detail.

### Materials and methods

*Pisces V* submersible dives and ROV deployments in the Au'au Channel between the islands of Maui and Lanai (Fig. 1) were conducted during scientific cruises in November 2001, December 2003, and September 2004. During each of these cruises, video transects were conducted in the same black coral bed in the north-central region of the Au'au Channel (the Keyhole Pinnacle area) to enable a time series comparison: three 2001 ROV transects (*RCV*-122, 123, and 124) consisting of 5.5 h of digital video covering approximately 5.8 km; one 2003

submersible dive (*PV*-553) with 6.8 h of digital video covering approximately 1.5 km; and one 2004 submersible dive (*PV*-568) with 7.5 h of digital video covering approximately 5.2 km. In 2004, an additional two submersible dives (*PV*-569 and 570) and three ROV deployments (*RCV*-283, 284, and 285) were conducted in other black coral beds in the Au'au Channel with a combined 10.5 h of digital video covering approximately 9.8 km.

In order to determine the *C. riisei* distribution pattern, water depth, colony height, and level of *C. riisei* overgrowth were recorded for each black coral colony observed. On the ROV and the submersible digital video, continuous depth data from a Seabird Electronics CTD profiler was used to record depth for each black coral colony. Temperature-depth profiles were also recorded. Due to mechanical difficulties, CTD data was not available for the 2003 submersible video.

In all the surveys the height of each black coral colony was estimated with the aid of parallel laser pointers set 15 cm apart. Colonies were classified as either: small < 40 cm; medium 40–75 cm; or large > 75 cm. The

small size class (<40 cm) corresponds to juvenile colonies that recruited to the population after the arrival of *C. riisei* to the Au'au Channel in the early 1990s. The medium size class (40–75 cm) corresponds to juvenile colonies that are on average less than 12 years old and are reproductively immature (Grigg 1976). The large size class corresponds to the reproductively mature segment of the population. The large colonies likely recruited to the population prior to the arrival of *C. riisei* in the Au'au Channel.

For each black coral colony observed, the level of *C. riisei* overgrowth (none/partial/total) and its state (alive/dead) was recorded. Further distinction was made if the black coral colony appeared to be recently dead. Recently dead black coral colonies retain their fine branches that erode with time eventually leaving only thick branches.

The 2001 and 2004 data were used to calculate the percentage of black coral colonies with *C. riisei* overgrowth at 5 m depth interval. The total number of black coral colonies within each 5 m depth interval was also tabulated. The lack of high-resolution depth data prevented a similar analysis with the 2003 video data.

Within each size class, the percentage of black coral colonies with and without *C. riisei* overgrowth was calculated. Chi-square tests were performed on the association of *C. riisei* overgrowth incidence with 5 m depth interval and with black coral size class. Within the Keyhole Pinnacle area, the 2001–2004 results were compared to identify possible trends with time.

During the 2003 and 2004 submersible dives, digital photos and video of black coral colony cohorts at all stages of *C. riisei* overgrowth were taken using a zoom lens. Samples of black coral with *C. riisei* overgrowth were taken using the submersible's mechanical arm for laboratory examination. Cases of *C. riisei* growth on open substrata and other benthic fauna were investigated qualitatively using the zoom lens in the digital video camera.

## Results

### Distribution patterns

Analyses of the 2001 and 2004 data showed that the percentage of black coral colonies with *C. riisei* overgrowth varied significantly by 5 m depth interval (chi-square  $p < 0.001$ ). The depth distribution of *C. riisei* relative to black corals showed a maximal impact between 80 and 105 m depth where >60% of all black coral colonies observed were at least partially overgrown with *C. riisei* (Fig. 3). The percentage of black coral colonies with *C. riisei* overgrowth declined to less than 10% at depths shallower than 70 m. All incidents of overgrowth observed shallower than 50 m consisted of small amounts of *C. riisei* restricted to the basal and interior regions of the black coral colonies. At these depths, *C. riisei* is abundant on the substrata but is

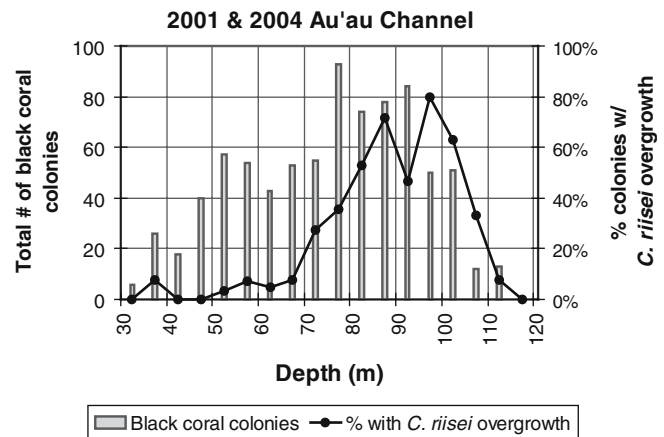


Fig. 3 Total number of black coral colonies recorded within each 5 m depth interval between 30 and 120 m and percentage of black coral colonies with partial or total *C. riisei* overgrowth ( $n = 807$ ) in the Au'au Channel

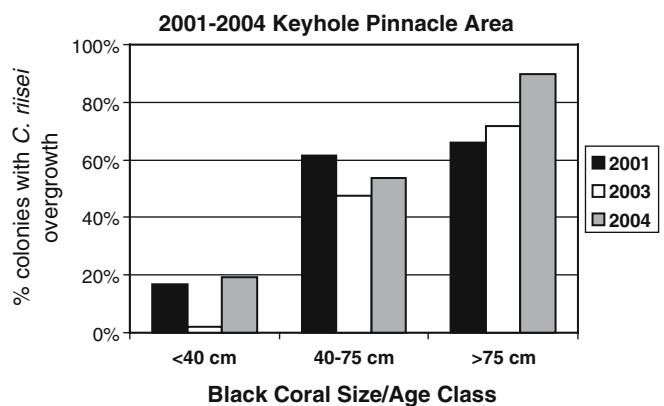


Fig. 4 Size class distribution of black coral colonies showing impact of *C. riisei* in 2001 ( $n = 159$ ), 2003 ( $n = 369$ ), and 2004 ( $n = 190$ ) between 70 and 120 m in the Keyhole Pinnacle area within the Au'au Channel. The large size class (>75 cm) corresponds to reproductively mature colonies while the small (>40 cm) and medium (40–75 cm) size class corresponds to juveniles

restricted to the shaded undersides of ledges and coral heads. The percentage of black coral colonies with *C. riisei* overgrowth also declined to less than 10% at depths deeper than 110 m. Black corals species *A. dichotoma* and *A. grandis* were not observed deeper than 115 m. *C. riisei* was also not observed on the substrata deeper than 115 m.

The distribution of *C. riisei* on black corals showed a significant association with age/size classes (chi-squared  $p < 0.0005$ ) (Fig. 4). Larger black coral colonies had a higher incidence of *C. riisei* overgrowth. In 2001, 2003, and 2004, less than 20% of the small, juvenile (>40 cm in height) black corals had *C. riisei* overgrowth while over 60% of the large, mature (>75 cm in height) black corals had *C. riisei* overgrowth. When *C. riisei* overgrowth was observed, the amount of overgrowth was typically very high. In 2004, 68% of black coral colonies



observed had total *C. riisei* overgrowth, 7% had partial overgrowth, and 25% were free of *C. riisei*.

Relative to the medium and large size classes, the small size class was probably underrepresented due to the visual limits in seeing the small colonies. Therefore, this frequency data may not reflect an accurate age/size class distribution for the small size class. The higher counts of black coral colonies observed via the submersible dives versus the ROV transects were due in part to the superior video survey capabilities associated with the submersible.

### Overgrowth investigations

Live black coral colonies were observed in all stages of *C. riisei* overgrowth from initial colonization covering less than 5% of surface area to >95% coverage (Fig. 2). *C. riisei* had overgrown on all recently dead black coral colonies. However, dead black coral colonies with heavily eroded skeletons were regularly observed to be free of *C. riisei* overgrowth. Black corals free of *C. riisei* overgrowth (both alive and dead) were often observed in close proximity to *C. riisei* on the substrata and on neighboring black corals.

In several instances an early stage of *C. riisei* overgrowth was associated with other epifauna on the black coral colony. Early *C. riisei* colonization was repeatedly observed on the shells of hammerhead oysters *Pterous* sp. and on bare skeletal portions of black coral colonies next to encrusting sponges. Laboratory examination of samples revealed that *C. riisei* readily attached to exposed black coral skeleton adjacent to live black coral tissue using an extensive network of overlapping stolons. Small black coral colonies were generally free of epifauna in contrast to most large otherwise healthy black coral colonies.

### Other observations

*C. riisei* was also observed colonizing open substrata. Colonization was observed on rugose features (i.e., large rocks, ledges, and corners) and areas immediately below overgrown black coral colonies. In 2003 and 2004, *C. riisei* was also observed colonizing large areas of more level, and gently sloping substrata at depths of 60–70 m, overgrowing large beds of scleractinian plate corals *Leptoseris* sp. and *Pavona* sp., and creating an underwater “prairie” of white polyps (Fig. 2). Close examination revealed that *C. riisei* was settling on the undersides of live plate corals with the axial polyp extending upward into the water column. Review of the 2001 video data reveals that while *C. riisei* was present in the plate coral beds, it was somewhat rare and inconspicuous. With the exception of the large size class (>75 cm), a yearly comparison of the percentage of black coral colonies with *C. riisei* overgrowth within the Keyhole Pinnacle area did not show an increasing trend

with time (Fig. 4). In terms of geographic distribution, the 2004 survey confirmed *C. riisei* overgrowth on black coral colonies at all locations investigated in the Au’au Channel.

## Discussion

The reduced frequency of *C. riisei* overgrowth shallower than 70 m is consistent with *C. riisei*'s avoidance of light in shallow water. Shallow-water *C. riisei* colonies transplanted into exposed sunlight (~25 m) exhibit tissue necrosis and subsequent death while control colonies transplanted within the shade do not (Kahng, unpublished data). The highest incidence of *C. riisei* overgrowth on black corals was observed between 80 and 105 m where photosynthetically active radiation (PAR) attenuates to less than 10% of surface values (Kirk 1994). Whether the apparent release with depth is due to direct effects of light irradiance or some other effect requires further investigation, but based on the present evidence, it appears that *C. riisei* is limited by the direct effects of irradiance.

The decrease in abundance of *C. riisei* at depths greater than 105 m in the Au’au Channel coincides with the top of the thermocline where temperature begins to decrease with increasing depth (Fig. 5). *C. riisei* was not observed on black corals or on the substrata deeper than 115 m. The thermocline may also account for the diminishing abundance of *A. dichotoma* and *A. grandis* at the same depth (Grigg 1976). Colder temperatures at greater depths may slow the growth rate of black coral and lead to a greater incidence of fouling by sponges, oysters, and bryozoans compared to similar sized colonies at shallower depths (Grigg, personal observation). However, the relative incidence of *C. riisei* overgrowth on black corals decreases near their lower depth limit

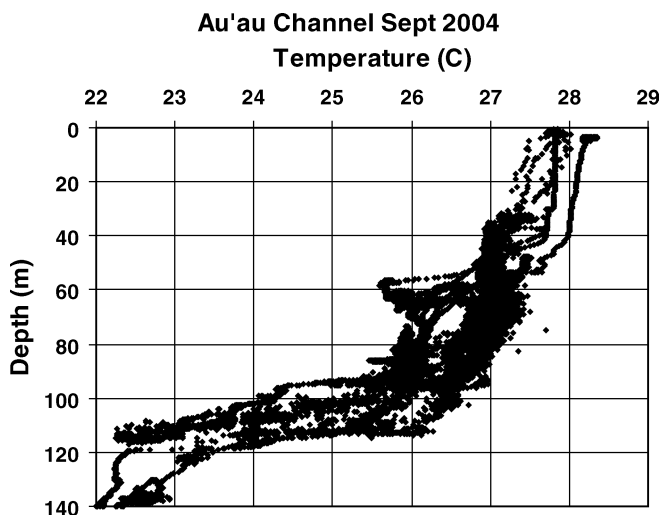


Fig. 5 Combined depth–temperature profile from *Pisces V* submersible dives and *RCV* remotely operated vehicle deployments conducted in September of 2004 in the Au’au Channel. Data were recorded by a CTD profiler at 1–5 s intervals

which suggests a lower depth or temperature related limit also applies to *C. riisei*.

Analysis by black coral age/size class shows an increasing incidence of *C. riisei* overgrowth with larger classes suggesting that size and exposure through time increase the cumulative probability of *C. riisei* settlement and overgrowth. *C. riisei* appears to settle on black coral colonies opportunistically. Patches of bare skeleton on black corals can be created by abrasion or localized senescence. The pattern of juvenile *C. riisei* colonies on hammerhead oyster shells attached to black coral colonies and on bare black coral skeletal surfaces created by receding sponge colonies suggests that certain epifauna facilitate *C. riisei* settlement onto black corals.

Once established on a black coral colony, *C. riisei* can quickly spread vegetatively and appears to adversely affect the host colony by smothering. The growth rate of *C. riisei* axial polyp extension of 0.5–2.0 cm per week (Rees 1969; Thomas 1979) is many times greater than that of black coral. Gut content analyses indicate *C. riisei* feed on zooplankton in the 200–1,200  $\mu\text{m}$  range (Kahng, unpublished data) which overlaps with the size class of black coral prey (Grigg 1964) and suggests the potential for competition for food.

Black coral colonies may also be susceptible to abrasion by *C. riisei* axial polyps creating additional bare skeletal surfaces for *C. riisei* colonization. The external surface of *C. riisei* colonies is covered by tough interlocking calcite spicules. In contrast, the living tissue of a black coral colony forms a fragile, gelatinous layer over a hard internal skeleton. Black coral colony polyps cannot retract and are always susceptible to damage.

The observations of live black coral colonies at all stages of *C. riisei* overgrowth were consistent with the *C. riisei* smothering hypothesis. No recently dead black coral colonies were observed to be free of *C. riisei* or at intermediate stages of overgrowth as would be expected if another factor was causing the large-scale mortality. Given *C. riisei*'s network of stolonal attachment on black coral colonies, wholesale detachment following colonization appears unlikely. However, *C. riisei* settlement onto new black coral substrata may be a somewhat limited opportunity. Both live black coral colonies and dead, eroded black coral skeletons were often observed to be completely free of *C. riisei* in close proximity to overgrown colonies. The resident epifauna on the eroded black coral skeletons may be inhibiting the *C. riisei* settlement.

The *C. riisei* invasion may significantly alter the population dynamics of black corals, especially if *C. riisei* continues to spread. Currently, Hawaiian black corals are harvested at depths shallower than 75 m (Grigg 2001). The zone of *C. riisei* overgrowth lies largely below current harvesting depths. However, this deeper population has been traditionally regarded as a reserve of large, highly fecund black coral colonies (Grigg 2001). With the *C. riisei* invasion of the Au'au Channel, black corals there now incur mortality from both invasion and harvesting.

In 2004, the preponderance of juvenile *C. riisei* colonies and the patchiness in many areas suggest that *C. riisei*'s biological invasion in the Au'au Channel has not yet peaked. Under favorable conditions in shallow water, *C. riisei* is regularly observed saturating the substrata and attaining densities of over 1,600 axial polyps per square meter (Kahng, unpublished data). The video record reveals *C. riisei*'s potential for deep water proliferation on flat, gently sloping, hard substrata deeper than 60 m (Fig. 2). At these depths, the overgrowth of large beds of scleractinian plate corals is similar to the behavior observed in the shaded habitat in shallow water (<40 m) where *C. riisei* has been observed settling and growing on inert parts of live benthic organisms such as bivalves and the undersides of scleractinian corals *Porites lobata* and *Montipora capitata* (Kahng, personal observation). While a comparison of the 2001–2004 results fails to detect a consistent trend of changing impact with time, natural variability, limited spatial coverage of the surveys, and small-scale differences in survey locations may mask any underlying change over this period.

The *C. riisei* biological invasion of Hawaii's coral reef community is a unique and significant event that warrants continued ecological research. Given the location of the benthic habitat in the Au'au Channel, the success of the *C. riisei* invasion appears to be independent of habitat alteration and anthropogenic disturbance—features that differentiates this biological invasion from many others (Orlans 1986; Lodge 1993; Carlton 1996). In terms of introduced biomass and displacement of native species, *C. riisei* may be the most invasive of the nonindigenous marine invertebrate in Hawaii. The low diversity and abundance of shallow-water octocorals may contribute to the susceptibility of Hawaii's coral reef community to *C. riisei*. Unfortunately, this susceptibility may apply to other nonindigenous octocoral species should they be introduced to Hawaii.

**Acknowledgements** We gratefully acknowledge the support of this research by grants from the University of Hawaii Undersea Research Laboratory (HURL) and the National Oceanic and Atmospheric Administration, Project# R/CR-8, sponsored by the University of Hawaii Sea Grant College Program, SOEST, under Institutional Grant No. NA16RG2254. The captain and crew of the R/V *Kaimikai-o-Kanaloa* provided surface support for all of the *Pisces V* submersible dives and *RCV* ROV deployments. Terry Kirby, Max Cremer, and Chuck Holloway, pilots of the *Pisces V* provided superb skill in operating the submersible.

## References

- Bayer F (1961) The shallow-water octocorallia of the West Indian region: a manual for marine biologists. Martinus Nijhoff, Dordrecht, pp 39–42
- Carlton JT (1996) Pattern, process and prediction in marine invasion ecology. *Biol Conserv* 78:97–106
- Coles S, Eldredge L (2002) Nonindigenous species introductions on coral reefs: a need for information. *Pac Sci* 56:191–209
- Coles S, DeFelice R, Eldredge L, Carlton J (1999) Historical and recent introductions of non-indigenous marine species into

- Pearl Harbor, Oahu, Hawaiian Islands. *Mar Biol* 135:147–158
- Davis SA (1977) Some aspects of the biology of *Anthelia edmondsoni* (Verrill) Department of Zoology. University of Hawaii, Honolulu
- Devaney D, Eldredge L (1977) Reef and shore fauna of Hawaii section 1: protozoa through Ctenophora. Bishop Museum, Honolulu
- Dinesen Z (1983) Patterns in the distribution of soft corals across the central Great Barrier Reef. *Coral Reefs* 1:229–236
- Eldredge L, Carlton J (2002) Hawaiian marine bioinvasions: a preliminary assessment. *Pac Sci* 56:211–212
- Evans EC, Buske NL, Grovhouh JG, Guinther EB, Jokiel PL, Kam DT, Kay EQ, Peeling TJ, Smith SV (1974) Pearl Harbor biological survey—final report. NUC TN 1128. Naval Undersea Center, San Diego
- Fabricius K, Alderslade P (2001) Soft Corals and Sea Fans: A comprehensive guide to the tropical shallow-water genera of the Central-West Pacific, the Indian Ocean, and the Red Sea. Australian Institute of Marine Science, Townsville MC
- Fenner D (2005) Corals of Hawai'i. A field guide to the hard, black, and soft corals of Hawai'i and the northwest Hawaiian Islands including midway. Mutual Publishing, Honolulu
- Grigg RW (1964) A contribution to the biology and ecology of the black coral, *Antipathes grandis* in Hawaii, Department of Zoology. University of Hawaii, Honolulu
- Grigg RW (1976) Fisheries management of precious and stony corals in Hawaii. University of Hawaii Sea Grant, 48 pp
- Grigg RW (2001) Black coral: history of sustained fishery in Hawaii. *Pac Sci* 55:291–299
- Grigg RW (2003) Invasion of a deep water coral bed by an alien species, *Carijoa riisei*. *Coral Reefs* 22:121–122
- Grigg RW (2004) Harvesting impacts and invasion by an alien species decrease estimates of black coral yield off Maui, Hawaii. *Pac Sci* 58:1–6
- Grigg RW, Bayer FM (1976) Present knowledge of the systematics and zoogeography of the order Gorgonacea in Hawaii. *Pac Sci* 30:167–175
- Hoover JP (1998) Hawaii's sea creatures. A guide to Hawai'i's marine invertebrates. Mutual Publishing, Honolulu
- Kirk JTO (1994) Light and photosynthesis in aquatic ecosystems. Cambridge University Press, New York
- Lodge DM (1993) Species invasions and deletions: community effects and responses to climate and habitat change. In: Kareiva P, Kingsolver J, Huey R (eds) Biotic interactions and global change. Sinauer Associates, Sunderland, pp 367–387
- Orians GH (1986) Site characteristics favoring invasions. In: Baker HG (ed) Ecology of biological invasions of North America and Hawaii. Springer, Berlin Heidelberg New York, pp 133–148
- Rees JT (1969) Aspects of growth and nutrition in the octocoral *Telesto riisei*, Department of Marine Sciences. University of Puerto Rico, Mayaguez, Puerto Rico
- Spalding MD, Ravilious C, Green EP (2001) World atlas of coral reefs. University of California Press, Berkeley
- Thomas W (1979) Aspects of the micro-community associated with *Telesto riisei* an introduced alcyonarian species, Department of Zoology. University of Hawaii, Honolulu
- Veron C (1995) Corals in time and space. University of South Wales Press, Australia