

## 7.21 Genus *Cyphastrea*

### 7.21.1 *Cyphastrea agassizi* Vaughan, 1907

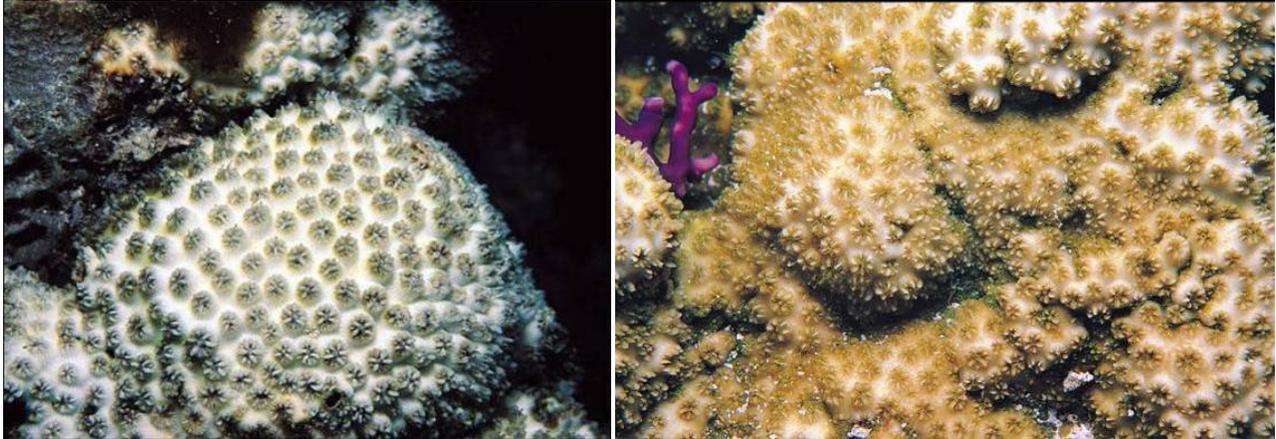


Figure 7.21.1. *Cyphastrea agassizi* photos from Veron (2000).

#### Characteristics

Colonies of *Cyphastrea agassizi* are massive, with deeply grooved surfaces, widely-spaced corallites, and a smooth coenosteum. Septae are in three unequal orders, with the first order exsert. May have irregular groove/tubercle formations (Veron, 2000). Colonies are usually only a few inches in diameter (Fenner, 2005). Colonies have a whitish coenosteum, with pale brown or green corallites. Septae are sometimes orange (Veron, 2000).

#### Taxonomy

**Taxonomic issues:** None. *Cyphastrea agassizi* is similar to *Cyphastrea ocellina* which has smaller, more crowded corallites. Superficially resembles *Cyphastrea japonica* and *Leptastrea inaequalis* (which has crowded corallites with thicker walls) (Veron, 2000).

**Family:** Faviidae.

**Evolutionary and geologic history:** The genus *Cyphastre* is known from the Oligocene Epoch from the Tethys Sea and West Indies, but is extinct in those locations (Wells and Moore, 1956).

#### Global Distribution

Found primarily in the Indo-Pacific, including Australia, Indonesia, Fiji, Japan, Hawai`i, and the Solomon Islands. *Cyphastrea agassizi* is also found in Bikini Atoll (Richards et al., 2008a).

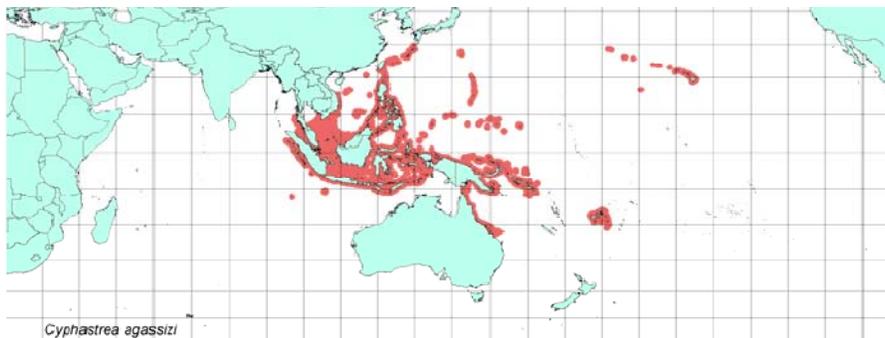


Figure 7.21.2. *Cyphastrea agassizi* distribution from IUCN copied from <http://www.iucnredlist.org>.

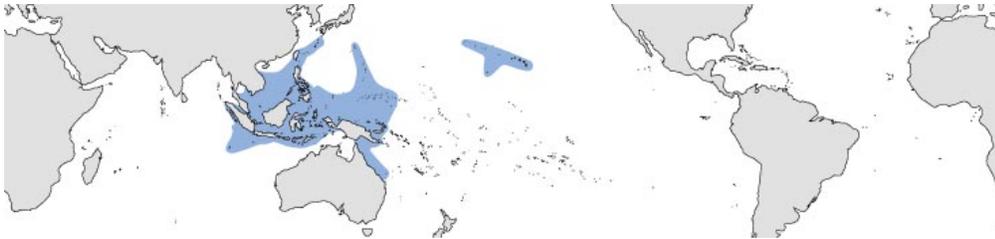


Figure 7.21.3. *Cyphastrea agassizi* distribution from Veron (2000).

## U.S. Distribution

According to both the IUCN Species Account and the CITES species database, *Cyphastrea agassizi* occurs in the Northern Mariana Islands. The IUCN Species Accounts also lists it for the U.S. minor outlying islands, and the CITES species database lists it for Hawai`i.

A search of published and unpublished records of occurrence in U.S. waters indicates *Cyphastrea agassizi* has been reported from Guam (Burdick, unpubl. data), the Commonwealth of the Northern Mariana Islands (CRED, unpubl. data), Hawai`i (Aki et al., 1994; Beets et al., 2010; Fenner, 2005; Godwin and Bolick, 2006), and Palmyra Atoll (Williams et al., 2008b).

Within federally protected waters, *Cyphastrea agassizi* has been recorded from the following areas:

- Pacific Remote Islands Marine National Monument (Palmyra)
- Marianas Trench Marine National Monument (Asuncion)
- Kaloko-Honokōhau National Historic Park, Hawai`i
- Kalaupapa National Historic Park, Molokai
- Hawaiian Islands Humpback Whale National Marine Sanctuary

## Habitat

**Habitat:** *Cyphastrea agassizi* has been reported from shallow reef environments (Veron, 2000). The species is found in back slopes, fore slopes, lagoons, and outer reef channels (IUCN, 2010).

**Depth range:** *Cyphastrea agassizi* has been reported in water depths ranging from 3 m to 20 m (Carpenter et al., 2008).

## Abundance

Abundance of *Cyphastrea agassizi* has been reported to be uncommon (Veron, 2000).

## Life History

The reproductive characteristics of *Cyphastrea agassizi* have not been determined. Congeners *Cyphastrea chalcidicum* and *Cyphastrea microphthalmia* are hermaphroditic spawners (Babcock et al., 1986; Willis et al., 1985), but *Cyphastrea ocellina* is a hermaphroditic brooder (Edmondson, 1929; Wright, 1986). The minimum size and age of first reproduction have not been determined for this species. However, for the congener *Cyphastrea ocellina*, the minimum size at first reproduction is 2 cm–3 cm, with an estimated age of first reproduction  $\leq 2$  years (Stimson, 1978; Wright, 1986). Larvae from spawned *Cyphastrea* do not contain zooxanthellae (Baird et al., 2009), but brooded *Cyphastrea* larvae do (Wright, 1986).

Photosynthetic performance of *Cyphastrea agassizi* is unremarkable. At lower light levels (100–300  $\mu\text{mol quanta/m}^2/\text{s}$ ), *Cyphastrea* has fluorescence yields and electron transport rates that are approximately average for the 68 species of corals surveyed in Sekisei Lagoon, Okinawa (Okamoto et al., 2005).

## Threats

**Thermal stress:** The genus *Cyphastrea* is generally resistant to bleaching. The genus was unaffected during the 1998 mass bleaching in the Great Barrier Reef (Marshall and Baird, 2000). However, elevated temperatures can still induce mortality in *Cyphastrea* even in the absence of bleaching (McClanahan, 2004).

**Acidification:** Unknown for the genus *Cyphastre*. However, in most corals studied (Table 3.2.2), acidification impairs growth (Langdon and Atkinson, 2005; Manzello, 2010) and, in the case of *Acropora palmata*, impairs fertilization and settlement success (Albright et al., 2010) and is likely to contribute to reef destruction in the future (Hoegh-Guldberg et al., 2007; Silverman et al., 2009). While ocean acidification has not been demonstrated to have caused appreciable declines in coral populations so far, the BRT considers it to be a significant threat to corals by 2100.

**Disease:** Unknown, but its congeners have been infected with diseases. *Cyphastrea chalcidicum* is susceptible to ciliate-induced skeletal eroding band (Antonius and Lipscomb, 2000), while *Cyphastrea microphthalma* in the United Arab Emirates have contracted yellow-band disease (Korrubel and Riegl, 1998). The ecological and population impacts of disease have not been established for *Cyphastrea agassizi*. However, ample evidence indicate that diseases can have devastating regional impacts on individual coral species (e.g., Aronson and Precht, 2001; Bruckner and Hill, 2009) and evidence show that these impacts are occurring in more taxa and at a broader geographic scale (Green and Bruckner, 2000; Sutherland et al., 2004).

**Predation:** Unknown for *Cyphastrea agassizi*.

**Land-based pollution (LBSP):** The effects of LBSP on *Cyphastrea agassizi* are largely unknown. LBSP-related stresses (nutrients, sediment, toxins, and salinity) often act in concert rather than individually and are influenced by other biological (e.g., herbivory) and hydrological factors. Collectively, LBSP stresses are unlikely to produce extinction at a global scale; however, they may pose significant threats at local scales (particularly important for species with limited range) and reduce the resilience of corals to bleaching (Carilli et al., 2009a; Wooldridge, 2009b).

**Collection/Trade:** This coral experiences light-to-moderate trade at the genus level (CITES, 2010). From 1993 to 2008, an average of 248 specimens were exported worldwide, although the majority of the trade is accounted for by an export of 2810 specimens from Indonesia in 1993.

## Risk Assessment

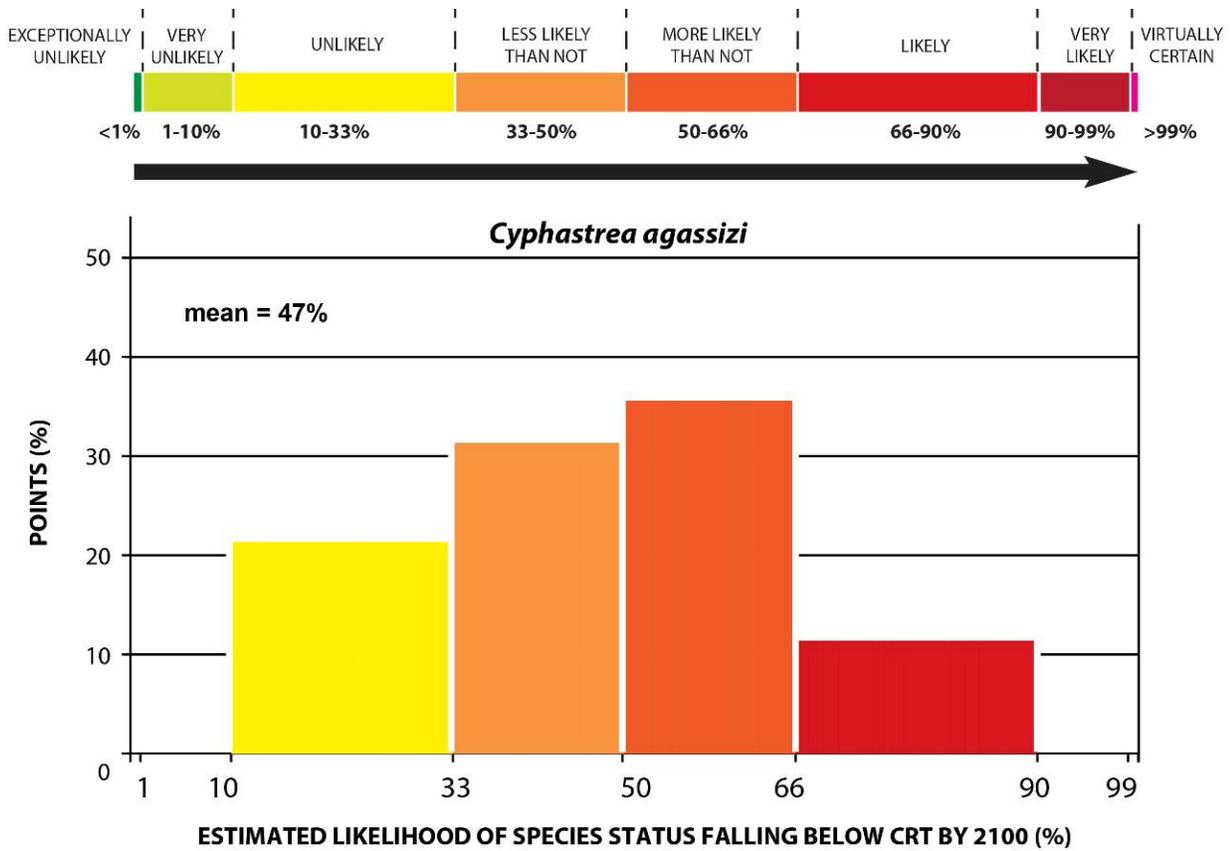


Figure 7.21.4. Distribution of points to estimate the likelihood that the status of *Cyphastrea agassizi* falls below the Critical Risk Threshold (the species is of such low abundance, or so spatially fragmented, or at such reduced diversity that extinction is extremely likely) by 2100.

*Cyphastrea agassizi* appears susceptible to disease, a factor that increases the potential extinction risk (higher likelihood of falling below the Critical Risk Threshold) for this species. *Cyphastrea agassizi* appears relatively resistant to bleaching, a factors that reduces the potential extinction risk (decrease the likelihood of falling below the Critical Risk Threshold).

The overall likelihood that *Cyphastrea agassizi* will fall below the Critical Risk Threshold by 2100 was estimated to be in the “less likely than not” risk category with a mean likelihood of 47% and a standard error (SE) of 14% (Fig. 7.21.4). This SE was calculated by taking the standard deviation of the seven mean voting scores of the BRT members and shows the coherence among the BRT. The uncertainty of the BRT is reflected in the range of votes of 10%–90% (Fig. 7.21.4) and the average range of likelihood estimates of the seven BRT voters (52%). The overall wide range of votes reflects the uncertainty among BRT members inherent in the lack of adequate ecological and demographic information for *Cyphastrea agassizi*.

### 7.21.2 *Cyphastrea ocellina* Dana, 1864



Figure 7.21.5. *Cyphastrea ocellina* photos from Veron (2000).

#### Characteristics

Colonies of *Cyphastrea ocellina* are massive or encrusting, with undulating surfaces (Veron, 2000). Colonies are often encrusting or knobby (Wright, 1986). They have tightly compact corallites, 3-mm diameter or smaller. Septa are in 2 unequal orders of 12 each, with a third order sometimes present. Paliform lobes are small or absent. Short spinules on coenosteum (Veron, 2000). In Hawai'i, *Cyphastrea ocellina* rarely grows more than 6 cm–8 cm in diameter (Edmondson, 1929) but can reach 15 cm (Maragos, 1977) or larger. Colonies are pale greenish-yellow or dark green in color (Veron, 2000).

#### Taxonomy

**Taxonomic issues:** None. *Cyphastrea ocellina* is similar to *Cyphastrea japonica*, which has unequal orders of septae and forms less massive colonies with grooves and tubercles often common (Veron, 2000).

**Family:** Faviidae.

**Evolutionary and geologic history:** The genus is known from the Oligocene Epoch from the Tethys Sea and West Indies, but is extinct in those locations (Wells and Moore, 1956).

#### Global Distribution

*Cyphastrea ocellina* is found in the Indo-Pacific, including the Great Barrier Reef in Australia, Indonesia, Japan, and the Philippines. It is also found in Hawai'i.

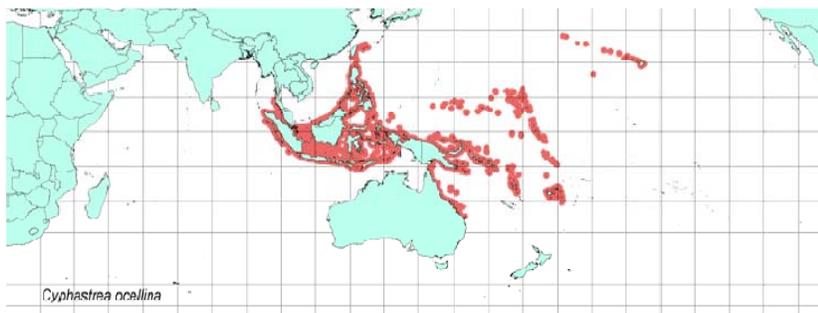


Figure 7.21.6. *Cyphastrea ocellina* distribution from IUCN copied from <http://www.iucnredlist.org>.



Figure 7.21.7. *Cyphastrea ocellina* distribution from Veron (2000).

## U.S. Distribution

According to both the IUCN Species Account and the CITES species database, *Cyphastrea ocellina* occurs in Hawai'i and the U.S. minor outlying islands.

A search of published and unpublished records of occurrence in U.S. waters indicates *Cyphastrea ocellina* has been reported from Hawai'i (Aki et al., 1994; Beets et al., 2010; Fenner, 2005; Godwin and Bolick, 2006; Maragos et al., 2004; Vaughan, 1907), Johnston Atol (CRED, unpubl. data; Maragos and Jokiel, 1986), and Kingman Reef (CRED, unpubl. data).

Within federally protected waters, *Cyphastrea ocellina* has been recorded from the following areas:

- Papahānaumokuākea Marine National Monument (Nihoa, Necker, French Frigate Shoals, Gardner Pinnacles, Maro Reef, Laysan, Lisianski, Pearl and Hermes, Midway)
- Pacific Remote Islands Marine National Monument (Johnston, Kingman)
- Kaloko-Honokōhau National Historic Park, Hawai'i
- Puukoholā Heiau National Historic Site, Hawai'i
- Kalaupapa National Historic Park, Molokai
- Hawaiian Islands Humpback Whale National Marine Sanctuary

## Habitat

**Habitat:** *Cyphastrea ocellina* has been reported to occupy upper reef slopes (Veron, 2000). Stimson (1978) reported *Cyphastrea ocellina* in shallow water only—reef flats, tide pools, and vertical rock in turbid shallow water. Wright (1986) reported that *Cyphastrea ocellina* typically colonizes dead substrate. According to an IUCN Red List report, the species is found on shallow upper reef slopes, lagoons, and outer channels (IUCN, 2010). Jokiel et al. (2007) reported the species on reef flats, reef crest, and fore reefs.

**Depth range:** *Cyphastrea ocellina* has been reported in water depths ranging from 5 m to 20 m (Carpenter et al., 2008).

## Abundance

Abundance of *Cyphastrea ocellina* has been reported as rare (Veron, 2000) or uncommon (Carpenter et al., 2008). It is not common in Hawai'i, but is found commonly enough that most of the physiology of the species is known from that location.

## Life History

*Cyphastrea ocellina* is a simultaneous hermaphrodite (Kolinski and Cox, 2003; Wright, 1986) that broods free-swimming, tentaculate, zooxanthellate planula larvae with distinctive white bodies at the oral end (Edmondson, 1929). Planulae are produced continuously and released year-round; planulation may be in phase with the new moon (Stimson, 1978) or unrelated to lunar phase (Edmondson, 1946). Colonies become gravid at a size of ~ 6 cm<sup>2</sup> (Stimson, 1978), but are less fecund than other brooders like *Pocillopora damicornis* (Wright, 1986), resulting in lower larval concentrations in the water column (Hodgson, 1985) and consequently, relative scarcity of *Cyphastrea ocellina* (Fitzhardinge, 1993). *Cyphastrea ocellina* larvae contain zooxanthellae (Wright, 1986).

Planulae can settle after 3 days, or remain unattached for over a month (Edmondson, 1929). Settled larvae tend to aggregate (Edmondson, 1946). Settled *Cyphastrea ocellina* can survive for up to 4 months without feeding, although

skeletal deposition is reduced under these conditions (Edmondson, 1929). Planulae can tolerate elevated temperatures; settled larvae can deposit skeletal material at elevated temperatures (30°C–31.5°C), but do not show high survival (Edmondson, 1929). Planulae can also tolerate brief periods (several days) of reduced salinity more effectively than Pocilloporid larvae (Edmondson, 1929) but die quickly in fresh water (Edmondson, 1946). *Cyphastrea ocellina* larvae can settle in acidic water (pH = 6) but do not survive (Edmondson, 1946).

Feeding responses (mouth opening, extension of mesenterial filaments) of *Cyphastrea ocellina* are stimulated by both live prey and amino acid extracts and peptides (Mariscal and Lenhoff, 1968). Lipid levels (~ 40% of dry tissue weight) in shallow-water *Cyphastrea ocellina* are at the higher end of the range found in Hawaiian corals, potentially serving as an energy reserve during stressful conditions (Stimson, 1987).

Growth is generally slow after settlement, often requiring 4 months to produce the first bud, with larger colonies growing ~ 2 mm/yr (Edmondson, 1929). More recent work shows faster growth rates—4.0 mm in 11 months (Romano, 1990), or as much as 1.4 cm/yr (pers. comm. in Stimson, 1978). Colonies, after 39 months of observation, reached a maximum size of 68.7 mm (Fitzhardinge, 1993).

*Cyphastrea ocellina* shows high aggression. It generally has a halo growing around it, often even excluding algae (Fitzhardinge, 1993). *Cyphastrea ocellina* uses extracoelenteric digestion to defend itself against faster-growing corals, but at a high energetic cost that reduces growth rates (Romano, 1990).

## Threats

**Thermal stress:** The genus *Cyphastrea* is generally resistant to bleaching. The genus was unaffected during the 1998 mass bleaching in the Great Barrier Reef (Marshall and Baird, 2000). However, elevated temperatures can still induce mortality in *Cyphastrea* even in the absence of bleaching (McClanahan, 2004). In Hawai'i *Cyphastrea ocellina* contains Clade C1 zooxanthellae (Thornhill, 2003), which may be relatively bleaching-tolerant (Smith et al., 2004b).

**Acidification:** Unknown for this genus *Cyphastrea*. However, in most corals studied (Table 3.2.2), acidification impairs growth (Langdon and Atkinson, 2005; Manzello, 2010) and, in the case of *Acropora palmata*, impairs fertilization and settlement success (Albright et al., 2010) and is likely to contribute to reef destruction in the future (Hoegh-Guldberg et al., 2007; Silverman et al., 2009). While ocean acidification has not been demonstrated to have caused appreciable declines in coral populations so far, the BRT considers it to be a significant threat to corals by 2100.

**Disease:** Unknown, but its congeners have been infected with diseases. *Cyphastrea chalcidicum* is susceptible to ciliate-induced skeletal-eroding band (Antonius and Lipscomb, 2000), while *Cyphastrea microphthalmia* in the United Arab Emirates have contracted yellow-band disease (Korrubel and Riegl, 1998). The ecological and population impacts of disease have not been established for *Cyphastrea ocellina*. However, ample evidence indicate that diseases can have devastating regional impacts on individual coral species (e.g., Aronson and Precht, 2001; Bruckner and Hill, 2009) and evidence show that these impacts are occurring in more taxa and at a broader geographic scale (Green and Bruckner, 2000; Sutherland et al., 2004).

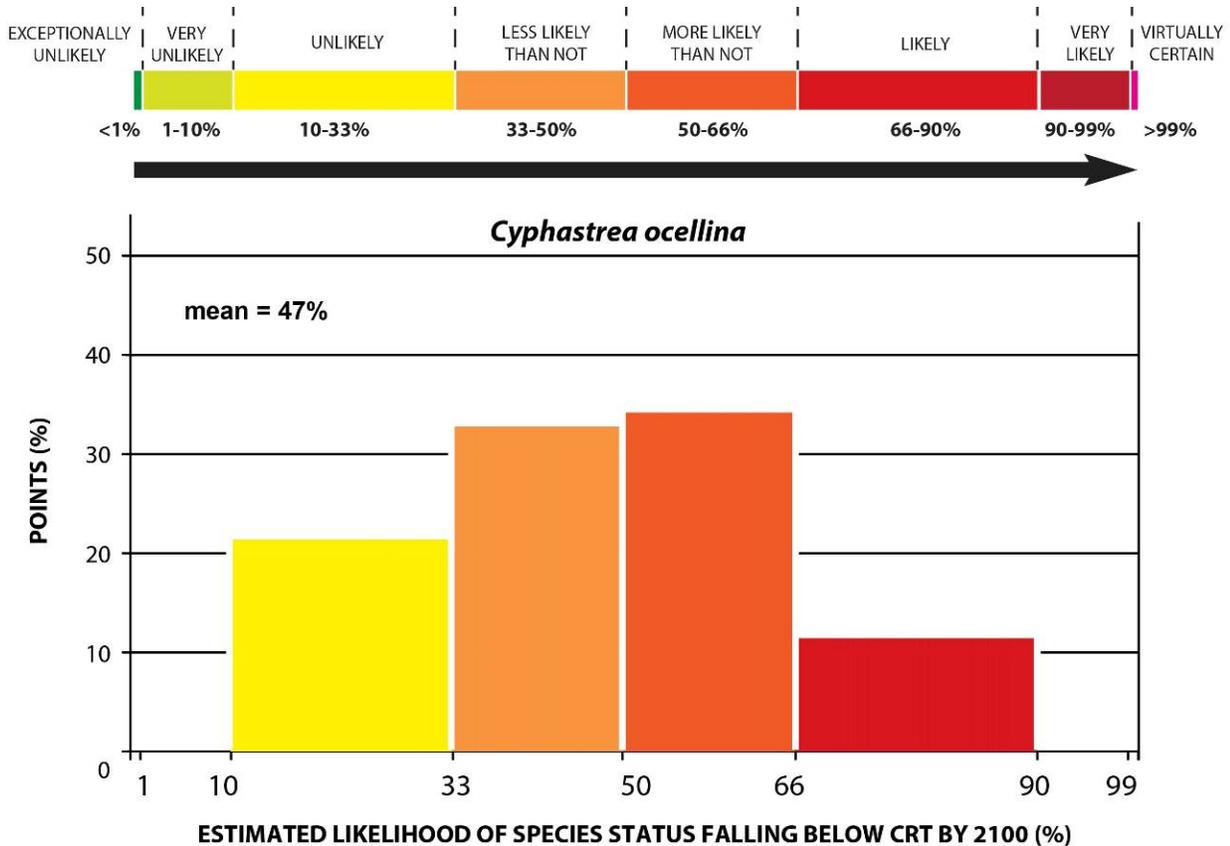
**Predation:** Unknown for *Cyphastrea ocellina*.

**Land-based sources of pollution (LBSP):** *Cyphastrea ocellina* may not compete well at high nutrient loads. The species rapidly recovered after sewage diversion reduced nutrient loads in Kāne'ohe Bay (Maragos et al., 1985) but rapidly crashed again during the *Dictyosphaeria cavernosa* bloom in 1990 (Evans, 1995).

LBSP-related stresses (nutrients, sediment, toxins, and salinity) often act in concert rather than individually and are influenced by other biological (e.g., herbivory) and hydrological factors. Collectively, LBSP stresses are unlikely to produce extinction at a global scale; however, they may pose significant threats at local scales (particularly important for species with limited range) and reduce the resilience of corals to bleaching (Carilli et al., 2009a; Wooldridge, 2009b).

**Collection/Trade:** This coral experiences light to moderate trade at the genus level (CITES, 2010). From 1993 to 2008, an average of 248 specimens were exported worldwide, although the majority of the trade is accounted for by an export of 2810 specimens from Indonesia in 1993. Only a single specimen identified as *Cyphastrea ocellina* was exported in 2002 (CITES, 2010).

## Risk Assessment



### ESTIMATED LIKELIHOOD OF SPECIES STATUS FALLING BELOW CRT BY 2100 (%)

Figure 7.21.8. Distribution of points to estimate the likelihood that the status of *Cyphastrea ocellina* falls below the Critical Risk Threshold (the species is of such low abundance, or so spatially fragmented, or at such reduced diversity that extinction is extremely likely) by 2100.

Factors that increase the potential extinction risk (higher likelihood of falling below the Critical Risk Threshold) for *Cyphastrea ocellina* are that it has experienced population fluctuations in the past resulting from LBSP stress. Factors that reduce potential extinction risk (decrease the likelihood of falling below the Critical Risk Threshold) are that *Cyphastrea ocellina* is likely relatively resistant to bleaching. Its life history and physiology may help it resist or recover from disturbance.

The overall likelihood that *Cyphastrea ocellina* will fall below the Critical Risk Threshold by 2100 was estimated to be in the “less likely than not” risk category with a mean likelihood of 47% and a standard error (SE) of 14% (Fig. 7.21.8). This SE was calculated by taking the standard deviation of the seven mean voting scores of the BRT members and shows the coherence among the BRT. The uncertainty of the BRT is reflected in the range of votes of 10%–90% (Fig. 7.21.8) and the average range of likelihood estimates of the seven BRT voters (52%). The overall wide range of votes reflects the uncertainty among BRT members inherent in the lack of adequate ecological and demographic information for *Cyphastrea ocellina*.

## 7.22 Genus *Euphyllia* (Family Caryophyllidae)

### 7.22.1 *Euphyllia cristata* Chevalier, 1971



Figure 7.22.1. *Euphyllia cristata* photos and corallite plan from Veron (2000).

#### Characteristics

Colonies of *Euphyllia cristata* are phaceloid, comprised of branching separate corallites. Corallites are closely compacted, 20 mm–40 mm diameter. Small solitary polyps are common. Primary septa are very exsert and are conspicuous underwater. First and second order septa plunge steeply near the centre of the corallite. There are no columellae. Polyps have large tubular tentacles with knob-like tips. Polyps are usually pale grey or green, with distinctively colored tips to the tentacles (Veron, 2000).

#### Taxonomy

**Taxonomic issues:** None.

**Family:** Caryophyllidae.

**Evolutionary and geologic history:** The genus is known from the Oligocene Epoch in the Tethys Sea and Caribbean but is extinct in those locations; known from the Eocene Age in Eurasia and the Indo-Pacific (Wells and Moore, 1956).

#### Global Distribution

*Euphyllia cristata* has a moderately wide range, including higher latitude areas in the Ryukus (Japan) and along both coasts of Australia. IUCN reports its existence off east Africa while Veron (2000) does not. It ranges east into the central Pacific.

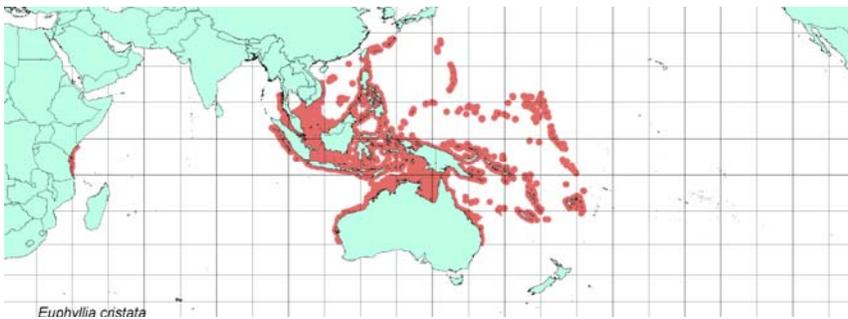


Figure 7.22.2. *Euphyllia cristata* distribution from IUCN copied from <http://www.iucnredlist.org>.

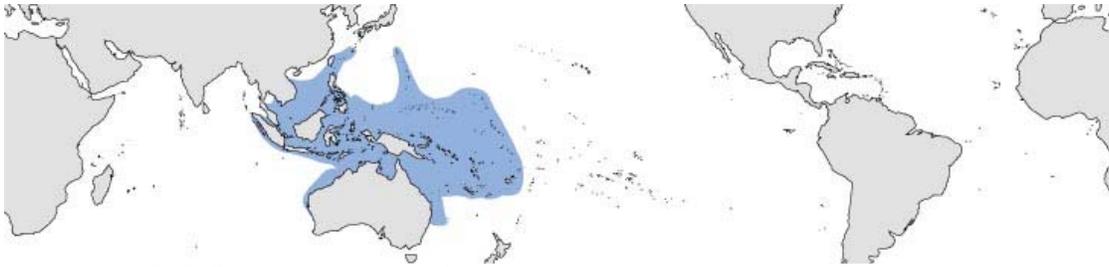


Figure 7.22.3. *Euphyllia cristata* distribution from Veron (2000).

## U.S. Distribution

According to the IUCN Species Account, *Euphyllia cristata* occurs in American Samoa and the Northern Mariana Islands. The CITES database does not list its occurrence in U.S. waters. A search of published and unpublished records of occurrence in U.S. waters indicates *Euphyllia cristata* has been reported from Tutuila in American Samoa (CRED, unpubl. data) and Guam (Randall, 2003).

Within federally protected waters, *Euphyllia cristata* has been recorded from:

- War in the Pacific National Historical Park, Guam.

## Habitat

**Habitat:** Veron (2000) describes *Euphyllia cristata* as inhabiting shallow reef habitats, while the IUCN account includes a wide depth range (see below).

**Depth range:** *Euphyllia cristata* occurs at depths of 1 m to 35 m (IUCN Species Account).

## Abundance

Abundance of *Euphyllia cristata* has been reported to be from common (Carpenter et al., 2008) to uncommon but conspicuous (Veron, 2000).

## Life History

Reproductive mode is not known for *Euphyllia cristata*. One congener (*Euphyllia ancora*) is a gonochoric spawner (Guest et al., 2005a; Willis et al., 1985) while another congener (*Euphyllia glabrescens*) is reported to be a hermaphroditic brooder in southern Taiwan (Fan et al., 2006). No other information regarding its ecology or life history is available.

## Threats

**Thermal stress:** *Euphyllia* species experienced high bleaching but mortality is unknown following the 1997/1998 mass bleaching event in Palau (Bruno et al., 2001). Congener *Euphyllia paraancora* in Taiwan contained both Clades C and D zooxanthellae, with Clade D primarily in stressful environments like shallow waters and reef edges (Chen et al., 2005).

**Acidification:** The effects of changes in ocean acidification are largely unknown for the genus *Euphyllia*. When raised in acidified conditions, congener *Euphyllia paradivisa* showed little change in skeletal morphology, while *Galaxea* and *Stylophora* showed substantial skeletal change and *Pocillopora* died (Tibbits, 2009). However, in most corals studied (Table 3.2.2), acidification impairs growth (Langdon and Atkinson, 2005; Manzello, 2010) and, in the case of *Acropora palmata*, impairs fertilization and settlement success (Albright et al., 2010) and is likely to contribute to reef destruction in the future (Hoegh-Guldberg et al., 2007; Silverman et al., 2009). While ocean acidification has not been demonstrated to have caused appreciable declines in coral populations so far, the BRT considers it to be a significant threat to corals by 2100.

**Disease:** Susceptibility and impacts of disease on *Euphyllia cristata* are not known. However, ample evidence indicate that diseases can have devastating regional impacts on individual coral species (e.g., Aronson and Precht, 2001;

Bruckner and Hill, 2009) and evidence show that these impacts are occurring in more taxa and at a broader geographic scale (Green and Bruckner, 2000; Sutherland et al., 2004).

**Predation:** Unknown for *Euphyllia cristata*.

**Land-based sources of pollution (LBSP):** The effects of LBSP are largely unknown for the genus *Euphyllia*. Abundance of *Euphyllia* recruits was enhanced in areas where fish were excluded, indicating it may be more tolerant of the shaded conditions created by increased algal biomass in overfished areas (Hughes et al., 2007). Congener *Euphyllia divisa* was fairly sensitive to exposure to cyanide; concentrations at or below those used in cyanide fishing caused a progressive tissue detachment, microbial infection, and death (Cervino et al., 2003). Large patches of *Euphyllia* sp. can form in turbid areas in Indonesia, suggesting a toleration of high sediment loads (Sandin et al., 2008).

LBSP-related stresses (nutrients, sediment, toxins, and salinity) often act in concert rather than individually and are influenced by other biological (e.g., herbivory) and hydrological factors. Collectively, LBSP stresses are unlikely to produce extinction at a global scale; however, they may pose significant threats at local scales (particularly important for species with limited range) and reduce the resilience of corals to bleaching (Carilli et al., 2009a; Wooldridge, 2009b).

**Collection/Trade:** *Euphyllia cristata* is heavily involved in the aquarium trade with species-specific exports or quotas from Indonesia, Fiji, Malaysia, and Tonga. Actual reported annual exports from Indonesia alone averaged over 36,000 pieces from 2000 to 2008 (CITES, 2010).

**Risk Assessment**

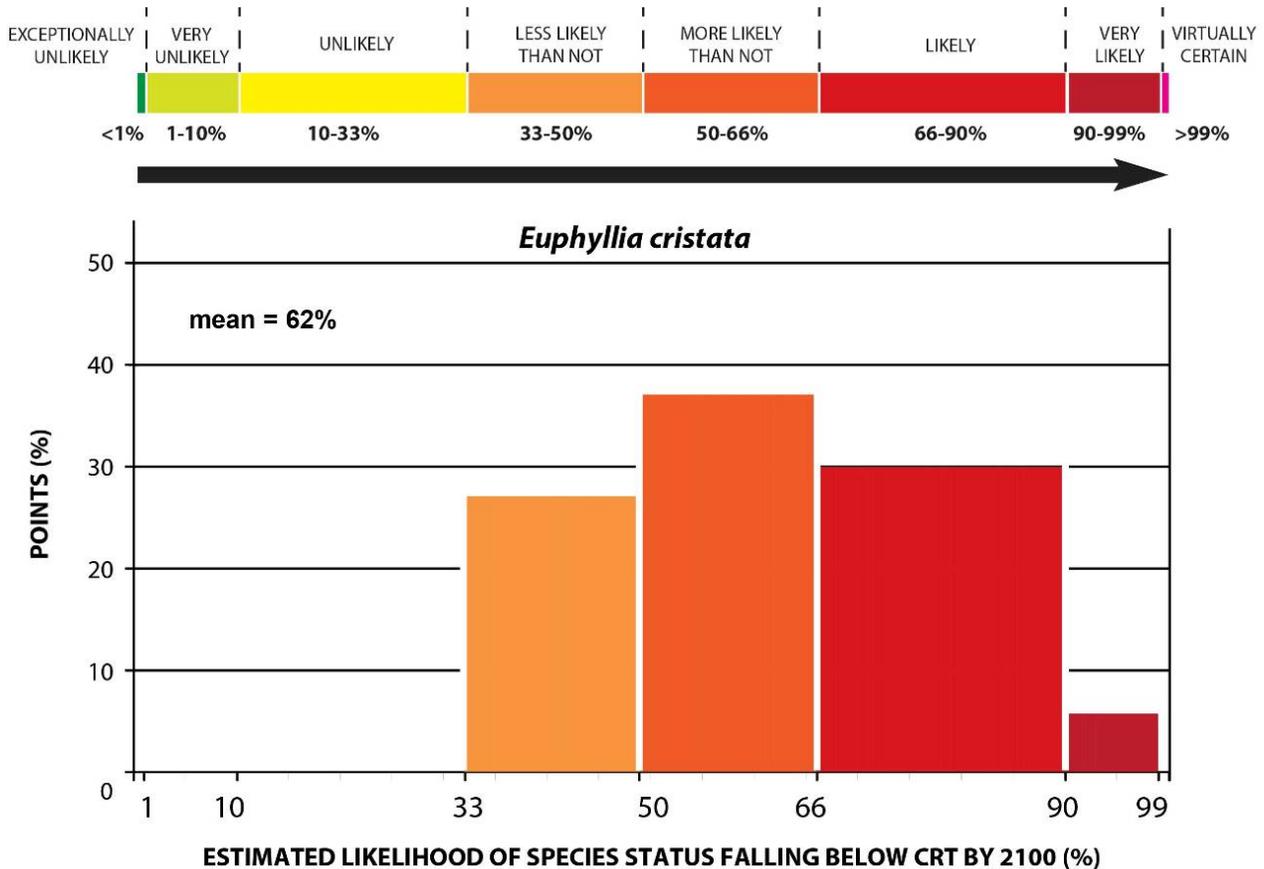


Figure 7.22.4. Distribution of points to estimate the likelihood that the status of *Euphyllia cristata* falls below the Critical Risk Threshold (the species is of such low abundance, or so spatially fragmented, or at such reduced diversity that extinction is extremely likely) by 2100.

Factors that increase the potential extinction risk (higher likelihood of falling below the Critical Risk Threshold) for *Euphyllia cristata* include its heavy involvement in international trade combined with its rare existence but conspicuous colonies, suggesting it is vulnerable to overexploitation. *Euphyllia cristata* appears to be susceptible to bleaching. Its geographic distribution range is moderate, although wider than its congeners under consideration in this review. Wide distribution lowers extinction risk by making it more likely a species will be able to escape the impacts of threats and catastrophes in at least some locations.

The overall likelihood *Euphyllia cristata* will fall below the Critical Risk Threshold by 2100 was estimated to be in the “more likely than not” risk category with a mean likelihood of 62% and a standard error (SE) of 11% (Fig. 7.22.4). This SE was calculated by taking the standard deviation of the seven mean voting scores of the BRT members and shows the coherence among the BRT. The uncertainty of the BRT is reflected in the range of votes of 33%–99% (Fig. 7.22.4) and the average range of likelihood estimates of the seven BRT voters (50%). The overall wide range of votes reflects the uncertainty among BRT members inherent in the lack of adequate ecological and demographic information for *Euphyllia cristata*.

### 7.22.2 *Euphyllia paraancora* Veron, 1990

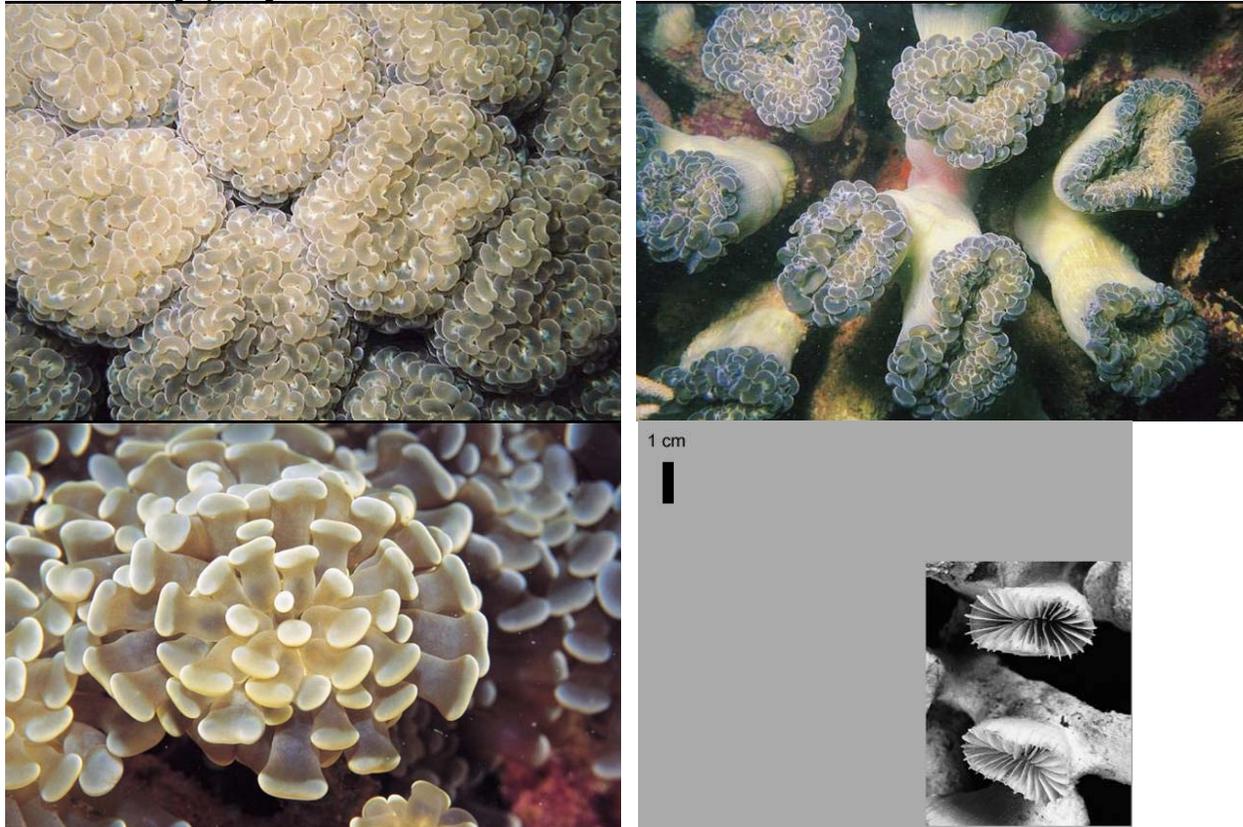


Figure 7.22.5. *Euphyllia paraancora* photos and corallite plan from Veron (2000).

#### Characteristics

Colonies of *Euphyllia paraancora* are phaceloid, comprised of branching separate corallites. Several species in this genus (including *Euphyllia glabrescens*, *Euphyllia paraglabrescens*, and *Euphyllia paradivisa*) cannot be distinguished based on skeletal characters, but only by the characters of polyp tentacles. Skeletons are similar to those of *Euphyllia glabrescens* with corallites 20 mm–40 mm diameter. Polyps have tentacles with anchor-shaped ends similar to those of *Euphyllia ancora*. Tentacle tips form concentric circles. Generally, colonies are pale tan or greenish-brown in color (Veron, 2000).

#### Taxonomy

**Taxonomic issues:** None.

**Family:** Carophyllidae.

**Evolutionary and geologic history:** The genus *Euphyllia* is known from the Oligocene Epoch in the Tethys Sea and Caribbean but is extinct in those locations; known from the Eocene Age in Eurasia and the Indo-Pacific (Wells and Moore, 1956).

#### Global Distribution

*Euphyllia paraancora* has a restricted range, both longitudinally and latitudinally. It is centered in the highly disturbed Coral Triangle Region. The IUCN indicates occurrence in the central Indian Ocean and in northern Australia which Veron (2000) does not support. It has been reported from Australia's Great Barrier Reef, Japan, and Hawai'i.

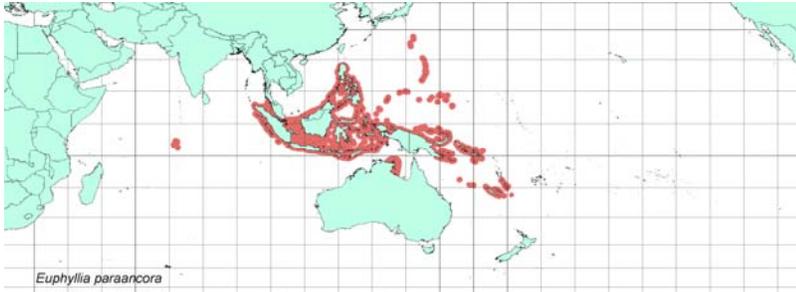


Figure 7.22.6. *Euphyllia paraancora* distribution from IUCN copied from <http://www.iucnredlist.org>.

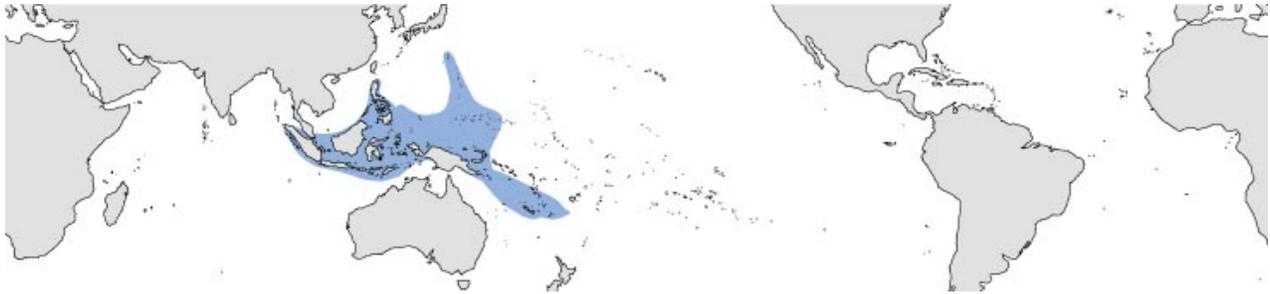


Figure 7.22.7. *Euphyllia paraancora* distribution from Veron (2000).

### U.S. Distribution

According to the IUCN Species Account, *Euphyllia paraancora* occurs in the Northern Mariana Islands. The CITES database does not list its occurrence in U.S. waters. A search of published and unpublished records of occurrence in U.S. waters indicates *Euphyllia paraancora* has been reported from Guam (D. Burdick unpubl. data). It has also been reported from videotape imagery recorded off Saipan in CNMI (D. Fenner pers. comm.).

*Euphyllia paraancora* has not been recorded from federally protected waters.

### Habitat

**Habitat:** *Euphyllia paraancora* has been reported from shallow and deep reef environments protected from wave action (Veron, 2000).

**Depth range:** *Euphyllia paraancora* has been reported in water depths ranging from 3 m to 30 m (Carpenter et al., 2008).

### Abundance

Abundance of *Euphyllia paraancora* has been reported to be uncommon (Veron, 2000). However, it has reportedly been found in monospecific carpets at 6 m to 8 m depth, creating a recognizable coral reef zone at the only location it's been reported in Taiwan (Hsieh et al., 2007).

### Life History

Reproductive mode is not known, although aquarium-maintained colonies of *Euphyllia paraancora* have been reported to release eggs 1 h before sunset and have also been reported to store eggs in polyp tentacles for 2 to 5 days before release (Borneman, 2006). One congener (*Euphyllia ancora*) is gonochoric spawner (Guest et al., 2005a; Willis et al., 1985) while another congener (*Euphyllia glabrescens*) is reported to be a hermaphroditic brooder in southern Taiwan (Fan et al., 2006). No other information regarding its ecology or life history is available.

## Threats

**Thermal stress:** *Euphyllia paraancora* and its congeners experienced high bleaching but mortality is unknown following the 1997/1998 mass bleaching event in Palau (Bruno et al., 2001). *Euphyllia paraancora* in Taiwan contained both Clades C and D zooxanthellae, with Clade D primarily in stressful environments like shallow waters and reef edges (Chen et al., 2005).

**Acidification:** The effects of changes in ocean acidification are largely unknown for the genus *Euphyllia*. When raised in acidified conditions, congener *Euphyllia paradivisa* showed little change in skeletal morphology, while *Galaxea* and *Stylophora* showed substantial skeletal change and *Pocillopora* died (Tibbitts, 2009). However, in most corals studied (Table 3.2.2), acidification impairs growth (Langdon and Atkinson, 2005; Manzello, 2010) and, in the case of *Acropora palmata*, impairs fertilization and settlement success (Albright et al., 2010) and is likely to contribute to reef destruction in the future (Hoegh-Guldberg et al., 2007; Silverman et al., 2009). While ocean acidification has not been demonstrated to have caused appreciable declines in coral populations so far, the BRT considers it to be a significant threat to corals by 2100.

**Disease:** Susceptibility and impacts of disease on *Euphyllia paraancora* are not known. However, ample evidence indicate that diseases can have devastating regional impacts on individual coral species (e.g., Aronson and Precht, 2001; Bruckner and Hill, 2009) and evidence show that these impacts are occurring in more taxa and at a broader geographic scale (Green and Bruckner, 2000; Sutherland et al., 2004).

**Predation:** Unknown for *Euphyllia paraancora*.

**Land-based sources of pollution (LBSP):** The effects of LBSP on the genus *Euphyllia* are largely unknown. Abundance of *Euphyllia* recruits was enhanced in areas where fish were excluded, indicating it may be more tolerant of the shaded conditions created by increased algal biomass in overfished areas (Hughes et al., 2007). Congener *Euphyllia divisa* was fairly sensitive to exposure to cyanide; concentrations at or below those used in cyanide fishing caused a progressive tissue detachment, microbial infection, and death (Cervino et al., 2003). Large patches of *Euphyllia* sp. can form in turbid areas in Indonesia, suggesting a toleration of high sediment loads (Sandin et al., 2008).

LBSP-related stresses (nutrients, sediment, toxins, and salinity) often act in concert rather than individually and are influenced by other biological (e.g., herbivory) and hydrological factors. Collectively, LBSP stresses are unlikely to produce extinction at a global scale; however, they may pose significant threats at local scales (particularly important for species with limited range) and reduce the resilience of corals to bleaching (Carilli et al., 2009a; Wooldridge, 2009b).

**Collection/Trade:** *Euphyllia* spp. are heavily involved in the aquarium trade. *Euphyllia paraancora* is specifically listed in the CITES databases with a 2008 annual export quota of ~ 5000 (up from 1000 in 2004) “maricultured” pieces from Indonesia although the meaning of “maricultured” is unclear. While *Euphyllia cristata* is the species listed in most of the wild-collected exports, the overlapping geographic range and the plethora of similar-looking species within this genus suggest that collection and trade may pose some degree of threat to this uncommon but conspicuous species which is in high international demand.

## Risk Assessment

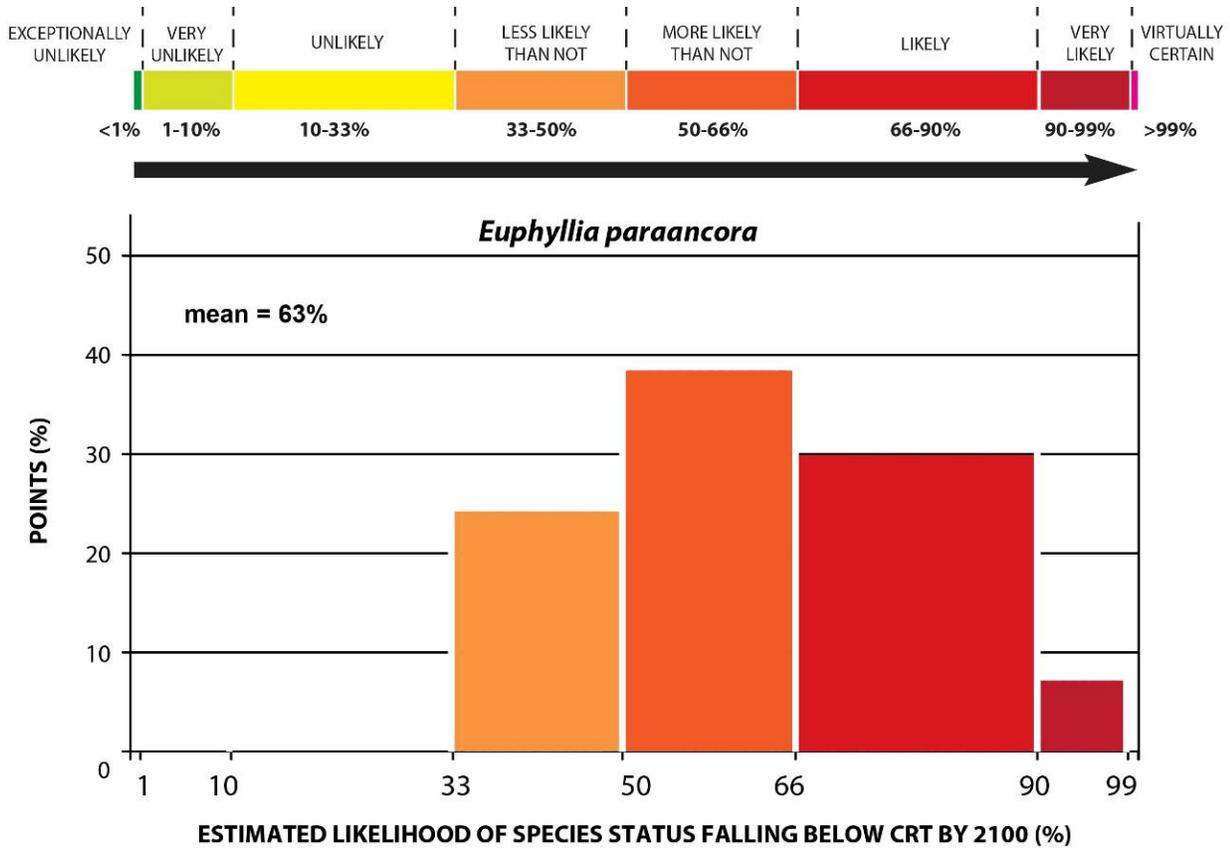


Figure 7.22.8. Distribution of points to estimate the likelihood that the status of *Euphyllia paraancora* falls below the Critical Risk Threshold (the species is of such low abundance, or so spatially fragmented, or at such reduced diversity that extinction is extremely likely) by 2100.

Factors that increase the potential extinction risk (higher likelihood of falling below the Critical Risk Threshold) for *Euphyllia paraancora* include its heavy involvement in international trade combined with its rare existence but conspicuous colonies, suggesting it is vulnerable to overexploitation. The species appears bleaching-susceptible. Its geographic distribution is also somewhat restricted, centered in the threat-prone Coral Triangle Region. Narrow geographic distribution increases the likelihood that changing conditions or a local impact in a particular location can push the species below the Critical Risk Threshold.

The overall likelihood *Euphyllia paraancora* will fall below the Critical Risk Threshold by 2100 was estimated to be in the “more likely than not” risk category with a mean likelihood of 63% and a standard error (SE) of 10% (Fig. 7.22.8). This SE was calculated by taking the standard deviation of the seven mean voting scores of the BRT members and shows a moderate degree of coherence among the BRT. The uncertainty of the BRT is reflected in the range of votes of 33%–99% (Fig. 7.22.8) and the average range of likelihood estimates of the seven BRT voters (50%). The overall wide range of votes reflects the uncertainty among BRT members inherent in the lack of adequate ecological and demographic information for *Euphyllia paraancora*.

### 7.22.3 *Euphyllia paradivisa* Veron, 1990



Figure 7.22.9. *Euphyllia paradivisa* photos and corallite plan from Veron (Veron, 2000).

#### Characteristics

Colonies are phaceloid, made up of branching separate corallites. Several species in this genus (including *Euphyllia glabrescens*, *Euphyllia paraglabrescens*, and *Euphyllia paraancora*) cannot be distinguished based on skeletal characters, but only by the characters of polyp tentacles. Polyps have branching tentacles almost identical to those of *Euphyllia divisa*. Color is pale greenish-grey with lighter tentacle tips (Veron, 2000).

#### Taxonomy

**Taxonomic issues:** None.

**Family:** Carophyllidae.

**Evolutionary and geologic history:** The genus *Euphyllia* is known from the Oligocene Epoch in the Tethys Sea and Caribbean but is extinct in those locations; known from the Eocene Period in Eurasia and the Indo-Pacific (Wells and Moore, 1956).

#### Global Distribution

*Euphyllia paradivisa* has a restricted range, existing only in the highly disturbed Coral Triangle Region.

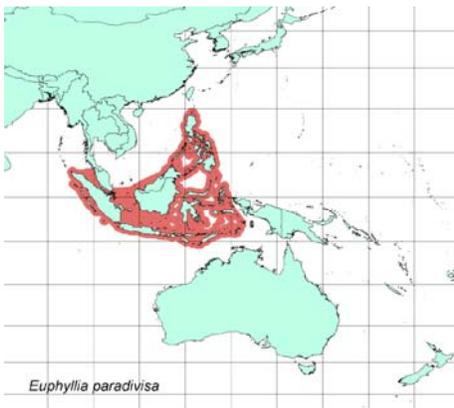


Figure 7.22.10. *Euphyllia paradivisa* distribution from IUCN copied from <http://www.iucnredlist.org>.



Figure 7.22.11. *Euphyllia paradivisa* distribution from Veron (2000).

### U.S. Distribution

According to the IUCN Species Account, *Euphyllia paradivisa* occurs in American Samoa, but no supporting reference is given. The CITES species database does not include any record of occurrence in U.S. waters. *Euphyllia paradivisa* is not listed as occurring in American Samoa in (Lovell and McLardy, 2008). Fenner reports *Euphyllia paradivisa* in Tutuila, American Samoa at Vatia Bay (unpubl. data, March 2010), supported by three photographs clearly showing the branching tentacles diagnostic of this species. It is very rare with only one small group of colonies found at about 25-m depth on a flat silt bottom. This species was not observed elsewhere in American Samoa by Fenner during dedicated surveys conducted at 38 sites off Ofu-Olosega, Ta'u, Rose Atoll, Swains, and South Bank in March 2010. No other published or unpublished data sources indicate the occurrence of *Euphyllia paradivisa* elsewhere in U.S. waters.

*Euphyllia paradivisa* has not been recorded from federally protected waters.

### Habitat

**Habitat:** *Euphyllia paradivisa* has been reported from shallow or mid-slope reef environments protected from wave action (Veron, 2000).

**Depth range:** *Euphyllia paradivisa* occurs at depths of 5 m to 20 m (IUCN Species Account).

### Abundance

Abundance of *Euphyllia paradivisa* has been reported to be uncommon (Veron, 2000).

### Life History

Reproductive mode is not known. One congener (*Euphyllia ancora*) is a gonochoric spawner (Guest et al., 2005a; Willis et al., 1985) while another congener (*Euphyllia glabrescens*) is reported to be a hermaphroditic brooder in southern Taiwan (Fan et al., 2006). No other information regarding its ecology or life history is available.

## Threats

**Thermal stress:** *Euphyllia* species experienced high bleaching but mortality is unknown following the 1997/1998 mass bleaching event in Palau (Bruno et al., 2001). Congener *Euphyllia paraancora* in Taiwan contained both Clades C and D zooxanthellae, with Clade D primarily in stressful environments like shallow waters and reef edges (Chen et al., 2005).

**Acidification:** The effects of changes in ocean acidification are largely unknown for the genus *Euphyllia*. When raised in acidified conditions, *Euphyllia paradivisa* showed little change in skeletal morphology, while *Galaxea* and *Stylophora* showed substantial skeletal change and *Pocillopora* died (Tibbits, 2009). However, in most corals studied (Table 3.2.2), acidification impairs growth (Langdon and Atkinson, 2005; Manzello, 2010) and, in the case of *Acropora palmata*, impairs fertilization and settlement success (Albright et al., 2010) and is likely to contribute to reef destruction in the future (Hoegh-Guldberg et al., 2007; Silverman et al., 2009). While ocean acidification has not been demonstrated to have caused appreciable declines in coral populations so far, the BRT considers it to be a significant threat to corals by 2100.

**Disease:** Susceptibility and impacts of disease on *Euphyllia paradivisa* are not known. However, ample evidence indicate that diseases can have devastating regional impacts on individual coral species (e.g., Aronson and Precht, 2001; Bruckner and Hill, 2009) and evidence show that these impacts are occurring in more taxa and at a broader geographic scale (Green and Bruckner, 2000; Sutherland et al., 2004).

**Predation:** Unknown for *Euphyllia paradivisa*.

**Land-based sources of pollution (LBSP):** The effects of LBSP on the genus *Euphyllia* are largely unknown. Abundance of *Euphyllia* recruits was enhanced in areas where fish were excluded, indicating it may be more tolerant of the shaded conditions created by increased algal biomass in overfished areas (Hughes et al., 2007). Congener *Euphyllia divisa* was fairly sensitive to exposure to cyanide; concentrations at or below those used in cyanide fishing caused a progressive tissue detachment, microbial infection, and death (Cervino et al., 2003). Large patches of *Euphyllia* sp. can form in turbid areas in Indonesia, suggesting a toleration of high sediment loads (Sandin et al., 2008).

LBSP-related stresses (nutrients, sediment, toxins, and salinity) often act in concert rather than individually and are influenced by other biological (e.g., herbivory) and hydrological factors. Collectively, LBSP stresses are unlikely to produce extinction at a global scale; however, they may pose significant threats at local scales (particularly important for species with limited range) and reduce the resilience of corals to bleaching (Carilli et al., 2009a; Wooldridge, 2009b).

**Collection/Trade:** *Euphyllia* spp. are heavily involved in the aquarium trade. *Euphyllia paradivisa* is specifically listed in the CITES databases with annual export quotas of up to 2380 “maricultured” pieces from Indonesia, although the meaning of “maricultured” is unclear. While *Euphyllia cristata* is the species listed in most of the wild-collected exports, the overlapping geographic range and the plethora of similar-looking species within this genus suggest that collection and trade may pose some degree of threat to an uncommon but conspicuous species which is in high international demand.

## Risk Assessment

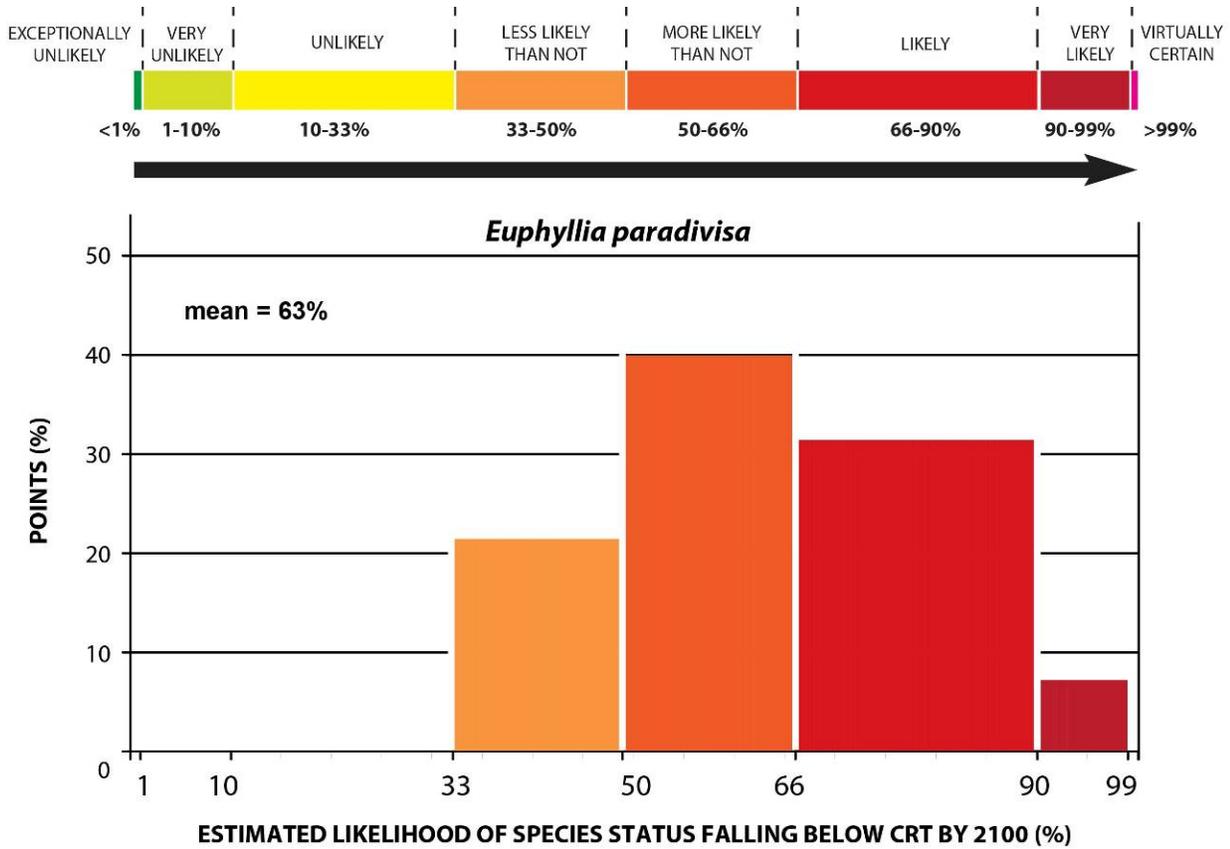


Figure 7.22.12. Distribution of points to estimate the likelihood that the status of *Euphyllia paradviva* falls below the Critical Risk Threshold (the species is of such low abundance, or so spatially fragmented, or at such reduced diversity that extinction is extremely likely) by 2100.

Factors that increase the potential extinction risk (higher likelihood of falling below the Critical Risk Threshold) for *Euphyllia paradviva* include its heavy involvement in international trade combined with its rare existence but conspicuous colonies, suggesting it is vulnerable to overexploitation. The species appears bleaching-susceptible. Its geographic distribution is also somewhat restricted, centered in the threat-prone Coral Triangle Region. Narrow geographic distribution increases the likelihood that changing conditions or a local impact in a particular location can push the species below the Critical Risk Threshold. No known factors were noted by the BRT to reduce the extinction risk of this species.

The overall likelihood *Euphyllia paradviva* will fall below the Critical Risk Threshold by 2100 was estimated to be in the “more likely than not” risk category with a mean likelihood of 63% and a standard error (SE) of 10% (Fig. 7.22.12). This SE was calculated by taking the standard deviation of the seven mean voting scores of the BRT members and shows a moderate degree of coherence among the BRT. The uncertainty of the BRT is reflected in the range of votes of 33%–99% (Fig. 7.21.12) and the average range of likelihood estimates of the seven BRT voters (50%). The overall wide range of votes reflects the uncertainty among BRT members inherent in the lack of adequate ecological and demographic information for *Euphyllia paradviva*.

## 7.23 Genus *Physogyra*

### 7.23.1 *Physogyra lichtensteini* Saville-Kent, 1871



Figure 7.23.1. *Physogyra lichtensteini* photos from Veron (2000).

#### Characteristics

Colonies of *Physogyra lichtensteini* are massive or thick, platy and meandroid forms with short, widely separated valleys and a light coenosteum. Colonies have large septa that are solid, smooth-edged, exsert, and widely spaced. They lack columellae. During the day, colonies often have a mass of grape-like or bifurcated vesicles that retract when disturbed. Tentacles are extended only at night. Colonies are pale grey in color, sometimes dull green (Veron, 2000).

There are conflicting reports on the maximum size of this species, ranging from 30 cm (Dinesen, 1983) to 150 cm (Veron and Pichon, 1980).

#### Taxonomy

**Taxonomic issues:** None. *Physogyra lichtensteini* is similar to *Pterogyra sinuosa* (Veron, 2000).

**Family:** Carophyllidae.

**Evolutionary and geologic history:** A recent Indo-Pacific genus with no known fossil record (Wells and Moore, 1956).

#### Global Distribution

*Physogyra lichtensteini* has a relatively broad distribution. It is found in Australia, Indonesia, Japan, Kenya, Madagascar, the Seychelles, the Red Sea, the Arabian Sea, India, the Philippines, and other areas in the west Pacific.

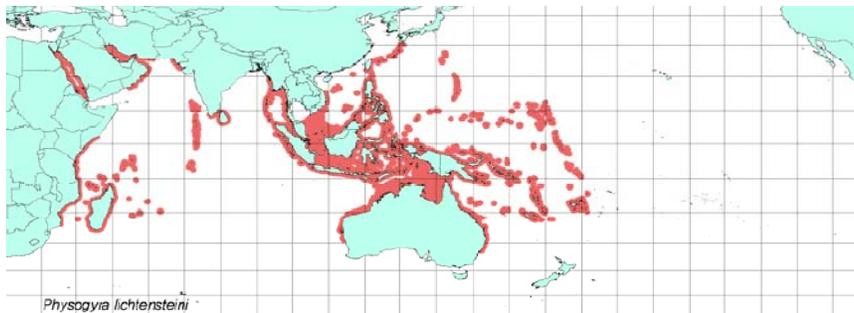


Figure 7.23.2. *Physogyra lichtensteini* distribution from IUCN copied from <http://www.iucnredlist.org>.



Figure 7.23.3. *Physogyra lichtensteini* distribution from Veron (2000).

## U.S. Distribution

According to the IUCN Species Account, *Physogyra lichtensteini* occurs in the Northern Mariana Islands, but no supporting reference is given. The CITES species database does not include any record of occurrence in U.S. waters.

Veron (2000) also lists the species in the Marianas; however, the Marianas record may be an error resulting from inaccurate geographic attribution of photographic evidence (Kenyon et al., 2010). Paulay (pers. comm., 28 February 2010) indicates a number of photos submitted by him to Veron from Palau and the Cook Islands, and other locations in the Pacific were mistakenly attributed to Guam (similar to the *errata* later acknowledged by Veron (2002) for *Acanthastrea regularis* and *Porites napopora*).

No other published or unpublished data sources indicate the occurrence of *Physogyra lichtensteini* elsewhere in U.S. waters.

## Habitat

**Habitat:** *Physogyra lichtensteini* has been reported to occupy turbid reef environments (Veron, 2000). The species is common in protected habitats (crevices and overhangs), especially in turbid water with tidal currents (Veron, 2000). *Physogyra lichtensteini* is also reported to be a cavernicolous species that prefers shallow but shaded waters, and it is found in caves on the Great Barrier Reef (Dinesen, 1982).

**Depth range:** *Physogyra lichtensteini* has been reported in water depths ranging from 1 m to 20 m (Carpenter et al., 2008).

## Abundance

Abundance of *Physogyra lichtensteini* has been reported to be common in protected habitats such as crevices and overhangs, especially in turbid water with tidal currents (Veron, 2000).

## Life History

*Physogyra lichtensteini* is a gonochoric broadcast spawner (Babcock et al., 1986; Willis et al., 1985). Larvae are lecithotrophic, i.e., they do not contain zooxanthellae (Baird et al., 2009). The minimum size and estimated age of first reproduction have not been determined for any members of the family (Harrison and Wallace, 1990). Larval longevity has not been determined in this family.

## Threats

**Thermal stress:** *Physogyra lichtensteini* has been identified as vulnerable to extinction due to its high bleaching rate, low diversity of its genus, and narrow habitat range (McClanahan et al., 2007). The species bleached at 31°C in Palau in 1998 (Bruno et al., 2001). *Physogyra lichtensteini* contains Clade C zooxanthellae in the South China Sea (Dong et al., 2009).

**Acidification:** Unknown for the genus *Physogyra*. However, in most corals studied (Table 3.2.2), acidification impairs growth (Langdon and Atkinson, 2005; Manzello, 2010) and, in the case of *Acropora palmata*, impairs fertilization and settlement success (Albright et al., 2010) and is likely to contribute to reef destruction in the future (Hoegh-Guldberg et

al., 2007; Silverman et al., 2009). While ocean acidification has not been demonstrated to have caused appreciable declines in coral populations so far, the BRT considers it to be a significant threat to corals by 2100.

**Disease:** Susceptibility and impacts of disease on *Physogyra lichtensteini* are not known. However, ample evidence indicates that diseases can have devastating regional impacts on individual coral species (e.g., Aronson and Precht, 2001; Bruckner and Hill, 2009) and evidence show that these impacts are occurring in more taxa and at a broader geographic scale (Green and Bruckner, 2000; Sutherland et al., 2004).

**Predation:** Population-level effects of predation are unknown for *Physogyra lichtensteini*, although it is preyed upon on by butterflyfish in Indonesia (Nagelkerken et al., 2009).

**Land-based sources of pollution (LBSP):** The effects of LBSP on *Physogyra lichtensteini* is unknown, but given that it prefers turbid waters the risk of sediment impacts are low. LBSP-related stresses (nutrients, sediment, toxins, and salinity) often act in concert rather than individually and are influenced by other biological (e.g., herbivory) and hydrological factors. Collectively, LBSP stresses are unlikely to produce extinction at a global scale; however, they may pose significant threats at local scales (particularly important for species with limited range) and reduce the resilience of corals to bleaching (Carilli et al., 2009a; Wooldridge, 2009b).

**Collection/Trade:** The genus *Physogyra* is heavily traded (CITES, 2010), primarily exported from Indonesia. Between 1999 and 2010, the trade quota for Indonesia has been on the order of ~ 10,000 specimens annually. Reported exports for *Physogyra lichtensteini* have been at or near these quotas, averaging 9912 specimens from 1999 to 2008 (CITES, 2010).

**Risk Assessment**

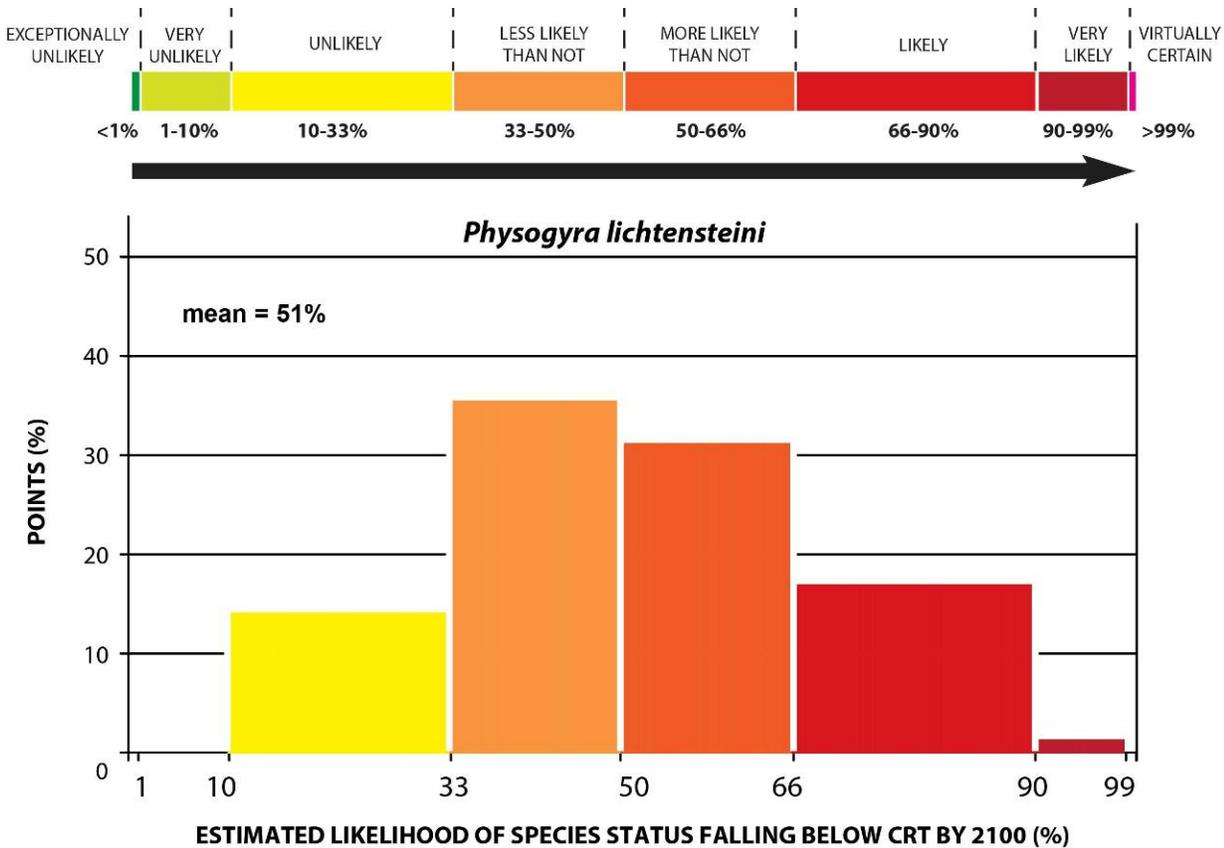


Figure 7.23.4. Distribution of points to estimate the likelihood that the status of *Physogyra lichtensteini* falls below the Critical Risk Threshold (the species is of such low abundance, or so spatially fragmented, or at such reduced diversity that extinction is extremely likely) by 2100.

Factors that increase the potential extinction risk (higher likelihood of falling below the Critical Risk Threshold) for *Physogyra lichtensteini* are that it has a high bleaching rate and is heavily collected. Factors that reduce potential extinction risk (decrease the likelihood of falling below the Critical Risk Threshold) are that *Physogyra lichtensteini* has a wide latitudinal distribution, is common, and tolerates difficult (turbid) environments. Wide distribution is considered to lower extinction risk by making it more likely a species will be able to escape the impacts of threats and catastrophes in at least some locations.

The overall likelihood that *Physogyra lichtensteini* will fall below the Critical Risk Threshold by 2100 was estimated to be in the “more likely than not” risk category with a mean likelihood score of 51% and a standard error (SE) of 11% (Fig. 7.23.4). This SE was calculated by taking the standard deviation of the seven mean voting scores of the BRT members and shows the coherence among the BRT. The uncertainty of the BRT is reflected in the range of votes of 10%–99% (Fig. 7.23.4) and the average range of likelihood estimates of the seven BRT voters (62%). *Physogyra lichtensteini* has the third-highest SE of the mean likelihood scores of all species (see Table 8.1 in Chapter 8). The overall wide range of votes reflects the uncertainty among BRT members inherent in the lack of adequate ecological and demographic information for this species. The variability also reflects the difficulty in reconciling its potential vulnerability to extinction from bleaching (McClanahan et al., 2007) with its wide range.

## 7.24 Genus *Turbinaria* (Family Dendrophylliidae)

### 7.24.1 *Turbinaria mesenterina* (Lamarck, 1816)



Figure 7.24.1. Colonies of *Turbinaria mesenterina* copied from Veron (2000).

#### Characteristics

Colonies of *Turbinaria mesenterina* are best known as large lettuce-like assemblages of plates with the polyps or corallites on the upper surfaces (Veron, 2000; see the *Turbinaria mesenterina* illustration in the center). The plates can be very contorted in shallow depths with a lot of water motion (see the *Turbinaria mesenterina* illustration to the left). In deeper water or low light conditions, the colonies can be large flat plates (see the *Turbinaria mesenterina* illustration to the right). *Turbinaria mesenterina* are usually grey-green or grey-brown in color.

#### Taxonomy

**Taxonomic issues:** None. The genus *Turbinaria* is quite distinct and is not confused with other genera. The species are usually quite distinguishable, especially when seen together. Some preliminary electrophoretic data suggested species groupings in *Turbinaria* that differ from classic taxonomic definitions (Ayre et al., pers. comm. in Willis, 1990), although since no further work has been done on the subject they are considered here as valid species.

**Family:** Dendrophylliidae.

**Evolutionary and geologic history:** *Turbinaria* originated in the Oligocene Epoch in the Tethys Sea in southern Europe (Wells and Moore, 1956). It went extinct in the Atlantic (Caribbean), but it still occurs across the Indian and Pacific Oceans.

#### Global Distribution

*Turbinaria mesenterina* has become very broadly distributed both longitudinally from east Africa and the Red Sea to eastern central Pacific and latitudinally from southern Africa and the Great Barrier Reef to Japan. *Turbinaria mesenterina* has the broadest distribution of the four species of *Turbinaria* considered in this review.

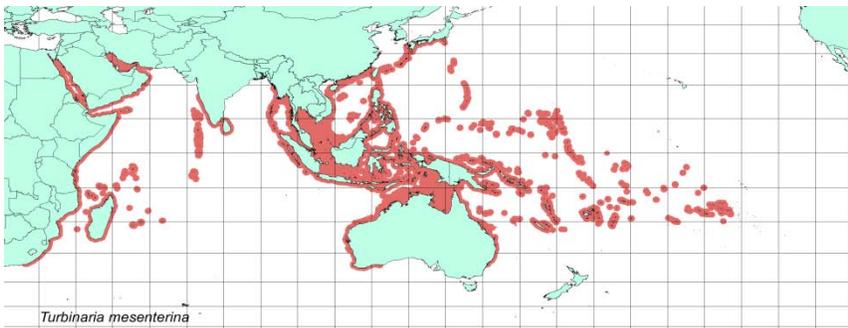


Figure 7.24.2. *Turbinaria mesenterina* distribution from IUCN copied from <http://www.iucnredlist.org>.



Figure 7.24.3. *Turbinaria mesenterina* distribution copied from Veron (2000).

## U.S. Distribution

*Turbinaria mesenterina* is found in Samoa. The IUCN Red Book lists *Turbinaria mesenterina* in the Marianas Islands, but Randall (1995) does not. According to both the IUCN Species Account and the CITES species database, *Turbinaria mesenterina* has been recorded in American Samoa. The IUCN Species Account also lists its occurrence in the Northern Mariana Islands and U.S. minor outlying islands.

A search of published and unpublished records of occurrence in U.S. waters indicates *Turbinaria mesenterina* has been reported from Tutuila, Ofu-Olosega, and Ta'u in American Samoa (Lovell and McLardy, 2008; National Park Service, 2009; C. Birkeland, unpubl. data; CRED, unpubl. data). Veron (2000) shows a distribution map including the Northern Mariana Islands (volume 2, page 394) but no independent published or unpublished reference has substantiated this record. Randall (1995) does not list *Turbinaria mesenterina* for the northern or southern islands in the Mariana Archipelago. No published or unpublished reference listing its occurrence in the U.S. minor outlying islands could be identified.

Within federally protected waters, *Turbinaria mesenterina* has been recorded from the following areas:

- National Park of American Samoa, Ofu Island unit.

## Habitat

**Habitat:** *Turbinaria mesenterina* can be a dominant species, forming massive and extensive stands, especially in shallow protected waters with some turbidity (Veron, 2000). *Turbinaria mesenterina* can live on forereef slopes and can prevail in clear water as well, but usually not in areas of heavy wave action.

**Depth range:** The depth range of *Turbinaria mesenterina* has been recorded as 3 m to 20 m (Titlyanov and Latypov, 1991; Veron and Pichon, 1980). Sheppard and Sheppard (1991) found *Turbinaria mesenterina* to occur commonly “at the base of reef slopes at 10 m or deeper.”

## Abundance

*Turbinaria mesenterina* has been reported to be common (Veron, 2000). The species can be locally dominant and form massive and extensive stands, especially in protected shallow turbid waters.

## Life History

The dominant sexual pattern in *Turbinaria mesenterina* is a gonochoric broadcast spawner, with a 1:1 sex ratio. However, a low incidence of hermaphroditism has been documented on the Great Barrier Reef (Babcock et al., 2003; Willis, 1987). Polyps nearest the growing plate edge are sterile or have lowered fecundity in their first year of growth, higher but sub-mature levels of fecundity after 2 or 3 years' growth, and are only fully fecund in their second spawning season, i.e., regions corresponding to 3 years or older. The minimum size at first reproduction is 12 cm to 16 cm, with an estimated age of 4 years (Willis, 1987). Planula larvae do not contain zooxanthellae that can supplement maternal provisioning with energy sources provided by their photosynthesis (Baird et al., 2009). Larval longevity has not been determined in this genus. Mean diameter of the corallum at settlement, in laboratory studies, is 900 µm (range 800–1000 µm) (Babcock et al., 2003; Willis et al., 1985).

## Threats

**Thermal stress:** Bleaching in *Turbinaria* varies among regions. The study by Marshall and Baird (2000) showed *Turbinaria* to be the most resistant to bleaching when responding to high seawater temperatures than any of the other 39 generic groups of scleractinians tested. *Turbinaria* were moderately vulnerable to bleaching in the western Indian Ocean from 1998 to 2005 (McClanahan et al., 2007), but that varied within that region—the genus bleached more in Mauritius than Kenya in 2004 (McClanahan et al., 2005a) and was one of the genera most resistant to bleaching in South Africa (Floros et al., 2004). Congeneric species had occasionally high bleaching and mortality occurrences in Palau from 1997 to 1998 (Bruno et al., 2001). It may be that some of the mixed bleaching response is determined by whether the stress is temperature- or light-induced, as repeated exposure to high irradiance significantly decreases the energy budget in *Turbinaria* (Hoogenboom et al., 2006). Alternatively, spatial differences in bleaching could be due to symbiont presence, as *Turbinaria* can host either Clade C or Clade D zooxanthellae (LaJeunesse et al., 2003; Ulstrup et al., 2006).

**Acidification:** A closely-related species, *Turbinaria reniformis*, appears to show a lower percent change in calcification when pCO<sub>2</sub> is doubled and tripled compared to the other genera of scleractinians experimentally tested (Kleypas et al., 2006). *Turbinaria reniformis* showed a 13% reduction in growth in high-CO<sub>2</sub> waters, but had no significant changes in skeletal microstructures (Marubini et al., 2003). Most corals studied have shown negative relationships between acidification and growth (Table 3.2.2) and acidification is likely to contribute to reef destruction in the future (Hoegh-Guldberg et al., 2007; Silverman et al., 2009). While ocean acidification has not been demonstrated to have caused appreciable declines in coral populations so far, the BRT considers it to be a significant threat to corals by 2100.

**Disease:** A white-syndrome disease has affected *Turbinaria* in Australia since 2000; elevated temperatures appear to significantly increase tissue loss (Dalton et al., 2010). Black lesions were also observed on *Turbinaria mesenterina* almost simultaneously with a bleaching event on the Great Barrier Reef (Jones et al., 2004). Also, ample evidence indicate that diseases can have devastating regional effects on individual coral species (e.g., Aronson and Precht, 2001; Bruckner and Hill, 2009) and evidence show that these effects are occurring in more taxa and at a broader geographic scale (Green and Bruckner, 2000; Sutherland et al., 2004).

**Predation:** Adult colonies of *Turbinaria* spp. are almost never eaten by crown-of-thorns seastars (Birkeland and Lucas 1990). *Turbinaria* are not thought to be eaten by *Phestilla sibogae* (Ritson-Williams et al., 2003), but recent evidence suggests that *Phestilla* can both feed on *Turbinaria* as well as infect it with disease (Dalton and Godwin, 2006).

**Land-base sources of pollution (LBSP):** *Turbinaria* spp. can be dominant in turbid waters. For both *Turbinaria reniformis* and *Turbinaria peltata*, Sheppard and Sheppard (1991) stated that “It coexists with *Turbinaria mesenterina* and is often found in sedimented conditions.” *Turbinaria mesenterina* maintains photosynthetic and growth rates even under highly turbid conditions (Sofonia and Anthony, 2008) and accumulates significant energy reserves (Anthony, 2006). As a genus, *Turbinaria* are efficient sediment-rejecters (Stafford-Smith and Ormond, 1992), but have been observed to incur partial mortality from sediment during dredging events (Blakeway, 2005). *Turbinaria* adopt funnel-shaped morphologies in turbid environments which localizes sediment effects to small portions of the colony (Riegl et al., 1996). *Turbinaria mesenterina* appears to tolerate low-salinity events, as it survived with little damage the 1991 cyclone floodwaters in the Keppel Islands (Van Woesik et al., 1995).

LBSP-related stresses (nutrients, sediment, toxins, and salinity) often act in concert rather than individually and are influenced by other biological (e.g., herbivory) and hydrological factors. Collectively, LBSP stresses are unlikely to produce extinction at a global scale; however, they may pose significant threats at local scales (particularly important for species with limited range) and reduce the resilience of corals to bleaching (Carilli et al., 2009a; Wooldridge, 2009b).

**Collection/Trade:** According to CITES records, *Turbinaria* spp. are one of the top 10 genera imported into the United States of America (U.S.A.). Between 1997 and 2001, more than 63,400 specimens were imported (Wabnitz, 2003) and between 2000 and 2008 around 370,000 pieces (between 30,000 and 50,000 per year) were reportedly exported from Indonesia that appears to be the main exporting country of *Turbinaria* spp. (CITES, 2010).

## Risk Assessment

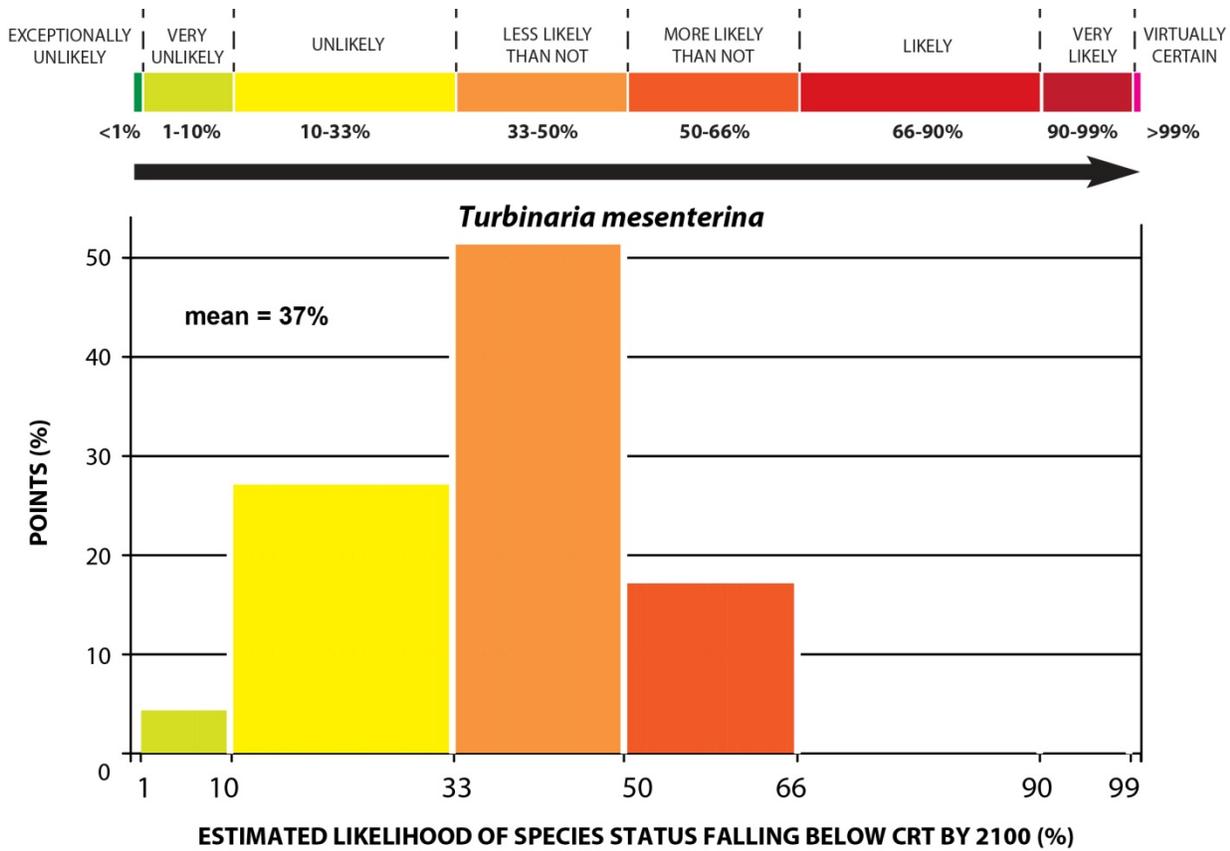


Figure 7.24.4. Distribution of points to estimate the likelihood that the status of *Turbinaria mesenterina* falls below the Critical Risk Threshold (the species is of such low abundance, or so spatially fragmented, or at such reduced diversity that extinction is extremely likely) by 2100.

Factors that increase the potential extinction risk (higher likelihood of falling below the Critical Risk Threshold) for *Turbinaria mesenterina* include susceptibility to disease and harvesting. *Turbinaria mesenterina* seems susceptible to disease at high latitudes in Australia. The aquarium trade appears to be the most immediate threat to populations of *Turbinaria*. Factors that reduce potential extinction risk (decrease the likelihood of falling below the Critical Risk Threshold) are that *Turbinaria mesenterina* can be dominant in turbid waters, is remarkably tolerant to seawater warming, low salinity events, lower pH, and predation, and is broadly distributed both latitudinally and longitudinally in the Indo-Pacific. Wide distribution is considered to lower extinction risk by making it more likely a species will be able to escape the impacts of threats and catastrophes in at least some locations

The overall likelihood that *Turbinaria mesenterina* will fall below the Critical Risk Threshold by 2100 was estimated to be in the “less likely than not” risk category with a mean likelihood of 37% and a standard error (SE) of 10% (Fig. 7.24.4). This SE was calculated by taking the standard deviation of the seven mean voting scores of the BRT members and shows the coherence among the BRT. The uncertainty of the BRT is reflected in the range of votes of 1%–66% (Fig. 7.24.4) and the average range of likelihood estimates of the seven BRT voters (45%). The overall wide range of votes reflects the uncertainty among BRT members inherent in the lack of adequate ecological and demographic information for *Turbinaria mesenterina*.

### 7.24.2 *Turbinaria peltata* (Esper, 1794)



Figure 7.24.5. Colonies of *Turbinaria peltata* copied from Veron (2000).

#### Characteristics

Colonies of *Turbinaria peltata* are best known as large lettuce-like assemblages of plates with the polyps or corallites on the upper surfaces of the laminae or leaves or blades or plates. The plates can be contorted in shallow depths with a lot of water motion (see the *Turbinaria peltata* illustration to the left; Veron, 2000). *Turbinaria peltata* can adopt a branching morphology (see the above illustration to the right).

*Turbinaria peltata* is usually grey-green or grey-brown in color.

#### Taxonomy

**Taxonomic issues:** None. The genus *Turbinaria* is quite distinct and is not confused with other genera. The species are usually quite distinguishable, especially when seen together. Some preliminary electrophoretic data suggested species groupings in *Turbinaria* that differ from classic taxonomic definitions (Ayre et al., pers. comm. in Willis, 1990), but no further work has been done on the subject so they are considered here as valid species.

**Family:** Dendrophylliidae.

**Evolutionary and geologic history:** *Turbinaria* originated in the Oligocene Epoch (Wells and Moore, 1956). It went extinct in the Atlantic (Caribbean), but it still occurs across the Indian and Pacific Oceans.

#### Global Distribution

*Turbinaria peltata* has become very broadly distributed both longitudinally (from east Africa to eastern central Pacific) and latitudinally (from southern Africa and the Great Barrier Reef to Japan). *Turbinaria peltata* has a slightly narrower distribution than *Turbinaria mesenterina* and *Turbinaria reniformis*, but slightly more extensive than *Turbinaria stellulata*. *Turbinaria peltata* is absent from the Red Sea.

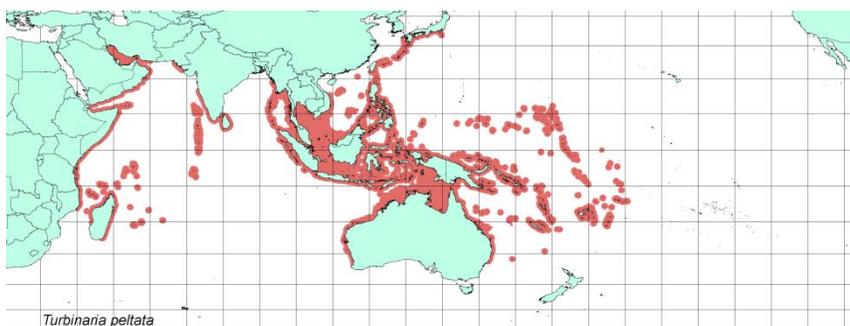


Figure 7.24.6. *Turbinaria peltata* distribution from IUCN copied from <http://www.iucnredlist.org>.



Figure 7.24.7. *Turbinaria peltata* distribution from Veron (2000).

## U.S. Distribution

According to both the IUCN Species Account and the CITES species database, *Turbinaria peltata* has been recorded in American Samoa. A search of published and unpublished records of occurrence in U.S. waters indicates *Turbinaria peltata* has been reported from Tutuila, Ta'u, and South Bank in American Samoa (Lamberts, 1983; Maragos et al., 1994; CRED unpubl. data). No published or unpublished references listing its occurrence in the U.S. minor outlying islands could be identified.

*Turbinaria peltata* has not been recorded from federally protected waters.

## Habitat

**Habitat:** *Turbinaria peltata* has been reported to occupy shallow protected waters with some turbidity (Veron, 2000). They can live on forereef slopes and can prevail in clear water as well, but usually not in areas of heavy wave action.

**Depth range:** The depth range of *Turbinaria peltata* has been recorded as 0 m–40 m. Sheppard and Sheppard (1991) found *Turbinaria peltata* to occur commonly “at the base of reef slopes at 10 m or deeper.”

## Abundance

*Turbinaria peltata* has been reported to be a common species that can be locally dominant and form massive and extensive stands, especially in protected shallow turbid waters (Veron, 2000).

## Life History

*Turbinaria peltata* is a broadcast spawner (Babcock et al., 1994; Kenyon, 1995), but its sexual pattern (hermaphrodite vs. gonochoric) has not been determined. However, three other species of *Turbinaria* all are gonochoric, although a low frequency of hermaphroditism has been shown on the Great Barrier Reef in the congener *Turbinaria mesenterina* (Willis, 1987). The minimum size and estimated age at first reproduction have not been determined for this species. However, for the congener *Turbinaria mesenterina*, the minimum size at first reproduction is 12 cm to 16 cm, with an estimated age of 4 years (Willis, 1987). Although specific observations have not been published for this species, the larvae of 2 other *Turbinaria* species studied do not contain zooxanthellae that can supplement maternal provisioning with energy sources provided by their photosynthesis (Baird et al., 2009).

## Threats

**Thermal stress:** Bleaching in *Turbinaria* varies among regions. The study by Marshall and Baird (2000) showed *Turbinaria* to be the most resistant to bleaching when responding to high seawater temperatures than any of the other 39 generic groups of scleratinians tested. *Turbinaria* were moderately vulnerable to bleaching in the western Indian Ocean from 1998 to 2005 (McClanahan et al., 2007), but that varied within that region—the genus bleached more in Mauritius than Kenya in 2004 (McClanahan et al., 2005a) and was one of the genera most resistant to bleaching in South Africa (Floros et al., 2004). Congeneric species had occasionally high bleaching and mortality in Palau in 1997–1998 (Bruno et al., 2001). It may be that some of the mixed bleaching response is whether the stress is temperature- or light-induced, as repeated exposure to high irradiance significantly decreases the energy budget in *Turbinaria* (Hoogenboom et al., 2006). Alternatively, spatial differences in bleaching could be attributed to symbiont presence, as *Turbinaria* can host either Clade C or Clade D zooxanthellae (LaJeunesse et al., 2003; Ulstrup et al., 2006).

**Acidification:** A congener *Turbinaria reniformis* appears to show a lower percent change in calcification when pCO<sub>2</sub> is doubled and tripled compared to the other genera of scleractinians experimentally tested (Kleypas et al., 2006). *Turbinaria reniformis* showed 13% reduction in growth in low-carbonate waters but had no significant changes in skeletal microstructures (Marubini et al., 2003). We might predict that this is a generic characteristic. However, most corals studied have shown negative relationships between acidification and growth (Table 3.2.2) and acidification is likely to contribute to reef destruction in the future (Hoegh-Guldberg et al. 2007, Silverman et al. 2009). While ocean acidification has not been demonstrated to have caused appreciable declines in coral populations so far, the BRT considers it to be a significant threat to corals by 2100.

**Disease:** A white-syndrome disease has affected *Turbinaria* in Australia since 2000; elevated temperatures appear to significantly increase tissue loss (Dalton et al., 2010). Black lesions were also observed on the closely related *Turbinaria mesenterina* almost simultaneously with a bleaching event on the Great Barrier Reef (Jones et al., 2004). Ample evidence indicate that diseases can have devastating regional effects on individual coral species (e.g., Aronson and Precht, 2001; Bruckner and Hill, 2009) and there is evidence that these effects are occurring in more taxa and at a broader geographic scale (Green and Bruckner, 2000; Sutherland et al., 2004).

**Predation:** Adult colonies of *Turbinaria* spp. are almost never eaten by crown-of-thorns seastars (Birkeland and Lucas 1990). *Turbinaria* are not thought to be eaten by *Phestilla sibogae* (Ritson-Williams et al., 2003), but recent evidence suggests that *Phestilla* can both feed on *Turbinaria* as well as infect it with disease (Dalton and Godwin, 2006).

**Land-base sources of pollution (LBSP):** *Turbinaria* spp. can be dominant in turbid waters. For both *Turbinaria reniformis* and *Turbinaria peltata*, Sheppard and Sheppard (1991) stated that “It coexists with *Turbinaria mesenterina* and is often found in sedimented conditions.” The closely related *Turbinaria mesenteria* maintains photosynthetic and growth rates even under highly turbid conditions (Sofonia and Anthony, 2008) and accumulates significant energy reserves (Anthony, 2006). As a genus, *Turbinaria* are efficient sediment rejecters (Stafford-Smith and Ormond, 1992), but have been observed to incur partial mortality from sediment during dredging events (Blakeway, 2005). *Turbinaria* adopt funnel-shaped morphologies in turbid environments and tends to localize sediment effects to small portions of the colony (Riegl et al., 1996).

*Turbinaria peltata* appears to tolerate low-salinity events, as it survived with little damage the 1991 cyclone floodwaters in the Keppel Islands (Van Woesik et al., 1995). LBSP-related stresses (nutrients, sediment, toxins, and salinity) often act in concert rather than individually and are influenced by other biological (e.g., herbivory) and hydrological factors. Collectively, LBSP stresses are unlikely to produce extinction at a global scale; however, they may pose significant threats at local scales (particularly important for species with limited range) and reduce the resilience of corals to bleaching (Carilli et al., 2009a; Wooldridge, 2009b).

**Collection/Trade:** According to CITES records, *Turbinaria* spp. are one of the top 10 genera imported into the USA. Between 1997 and 2001, more than 63,400 specimens were imported (Wabnitz, 2003) and between 2000 and 2008 around 370,000 pieces (between 30,000 and 50,000 per year) were reportedly exported from Indonesia that appears to be the main exporting country of *Turbinaria* spp (CITES, 2010).

## Risk Assessment

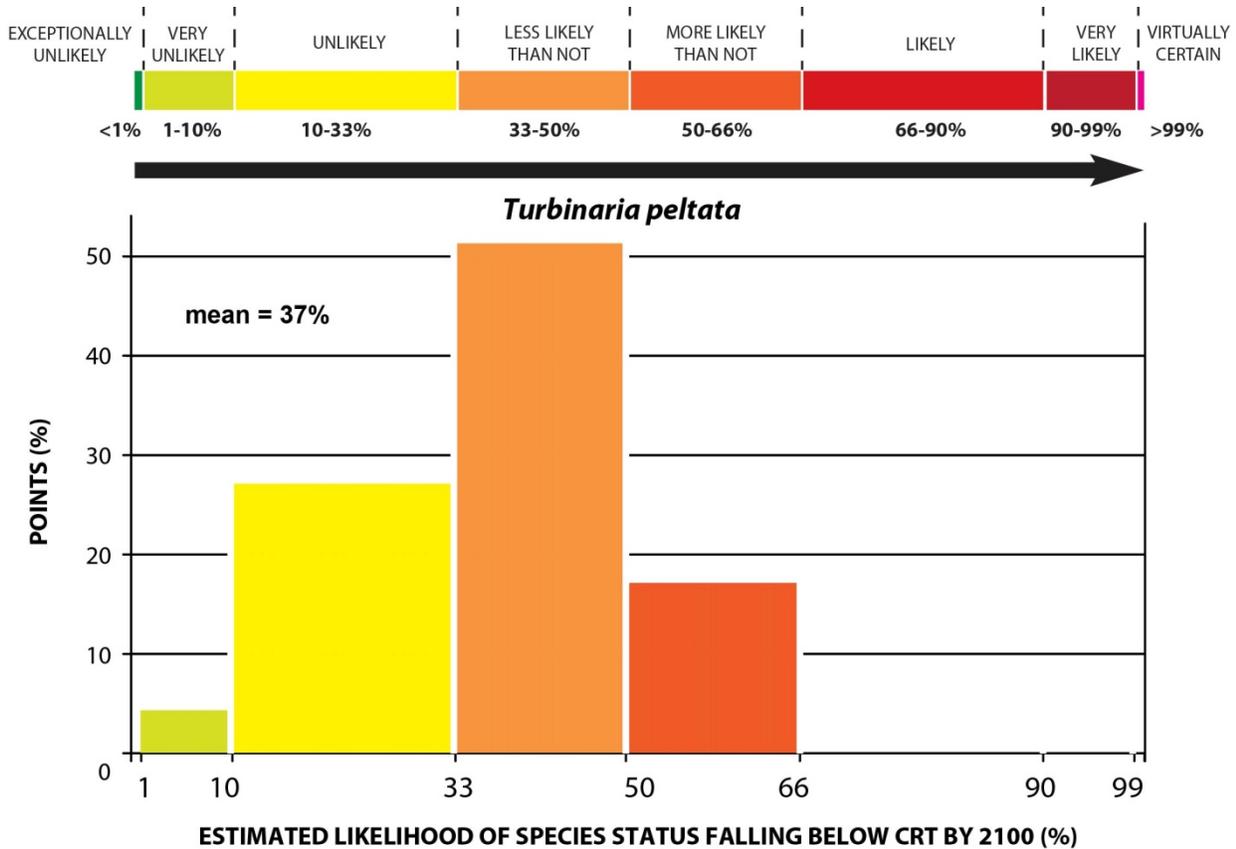


Figure 7.24.8. Distribution of points to estimate the likelihood that the status of *Turbinaria peltata* falls below the Critical Risk Threshold (the species is of such low abundance, or so spatially fragmented, or at such reduced diversity that extinction is extremely likely) by 2100.

Factors that increase the potential extinction risk (higher likelihood of falling below the Critical Risk Threshold) for *Turbinaria peltata* include susceptibility to disease and harvesting. *Turbinaria peltata* seems susceptible to disease at high latitudes in Australia. The aquarium trade appears to be the most immediate threat to populations of *Turbinaria*. Factors that reduce potential extinction risk (decrease the likelihood of falling below the Critical Risk Threshold) are that *Turbinaria peltata* can be dominant in turbid waters, is remarkably tolerant to seawater warming, low salinity events, lower pH, and predation, and is broadly distributed both latitudinally and longitudinally in the Indo-Pacific. Wide distribution is considered to lower extinction risk by making it more likely a species will be able to escape the impacts of threats and catastrophes in at least some locations

The overall likelihood that *Turbinaria peltata* will fall below the Critical Risk Threshold by 2100 was estimated to be “less likely than not” with a mean likelihood of 37% probability and a standard error (SE) of 10% (Fig. 7.24.8). This SE was calculated by taking the standard deviation of the seven mean voting scores of the BRT members and shows the coherence among the BRT. The uncertainty of the BRT is reflected in the range of votes of 1%–66% (Fig. 7.23.3) and the average range of likelihood estimates of the seven BRT voters (45%). The overall wide range of votes reflects the uncertainty among BRT members inherent in the lack of adequate ecological and demographic information for *Turbinaria peltata*.

### 7.24.3 *Turbinaria reniformis* Bernard, 1896

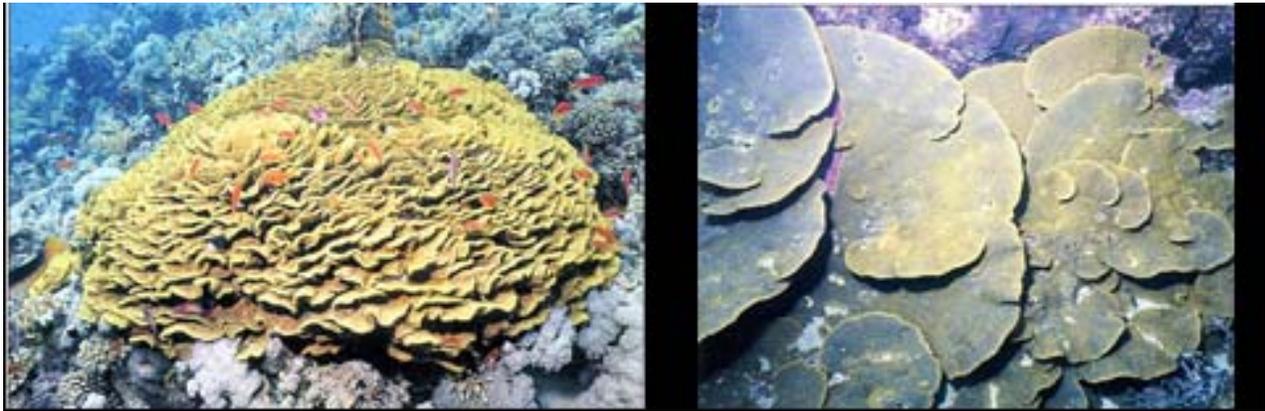


Figure 7.24.9. Colonies of *Turbinaria reniformis* copied from Veron (2000).

#### Characteristics

*Turbinaria reniformis* are best known as large lettuce-like assemblages of plates with the polyps or corallites on the upper surfaces of the laminae or leaves or blades or plates (see the *Turbinaria reniformis* illustration to the left). The plates can be very contorted in shallow depths with a lot of water motion. In deeper water or low light conditions, the colonies can form large flat plates (see the *Turbinaria reniformis* illustration to the right) (Veron, 2000). *Turbinaria* are usually grey-green or grey-brown in color, although *Turbinaria reniformis* usually displays some bright yellow, especially at the margins.

#### Taxonomy

**Taxonomic issues:** None. The genus *Turbinaria* is quite distinct and is not confused with other genera. The species are usually quite distinguishable, especially when seen together. Some preliminary electrophoretic data suggested species groupings in *Turbinaria* that differ from classic taxonomic definitions (Ayre et al., pers. comm. in Willis, 1990), but no further work has been done on the subject and so they are considered here as valid species.

**Family:** Dendrophylliidae.

**Evolutionary and geologic history:** *Turbinaria* originated in the Oligocene Epoch in the Tethys Sea in southern Europe (Wells and Moore, 1956). It went extinct in the Atlantic (Caribbean), but it still occurs across the Indian and Pacific Oceans.

#### Global Distribution

*Turbinaria reniformis* has become very broadly distributed both longitudinally (from east Africa and the Red Sea to eastern central Pacific) and latitudinally (from southern Africa and the Great Barrier Reef to Japan). *Turbinaria reniformis* is absent from eastern Australia and southern Africa.

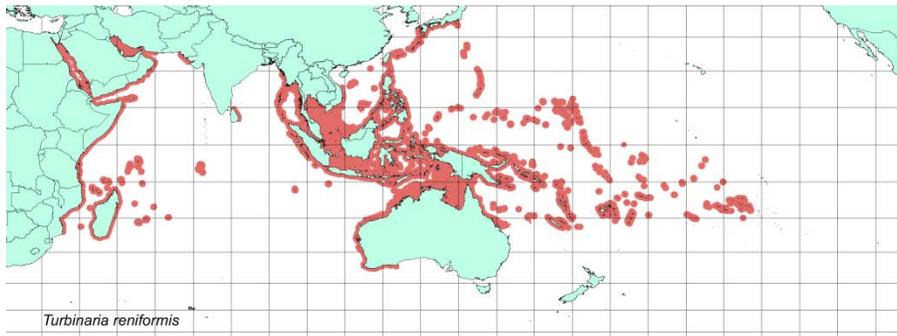


Figure 7.24.10. *Turbinaria reniformis* distribution from IUCN copied from <http://www.iucnredlist.org>.



Figure 7.24.11. *Turbinaria reniformis* distribution from Veron (2000).

## U.S. Distribution

*Turbinaria reniformis* is found in Samoa. According to both the IUCN Species Account and the CITES species database, *Turbinaria reniformis* has been recorded in American Samoa. The IUCN Species Account and Randall (1995) also list its occurrence in the Northern Mariana Islands, southern Mariana Islands (including Guam) and U.S. minor outlying islands.

A search of published and unpublished records of occurrence in U.S. waters indicates *Turbinaria reniformis* has been reported from Tutuila, Ofu-Olosega, Ta'u, and Rose Atoll in American Samoa (Coles et al., 2003; Fisk and Birkeland, 2002; Kenyon et al., 2010a; Lovell and McLardy, 2008; Maragos et al., 1994; Mundy, 1996; National Park Service, 2009; C. Birkeland, unpubl. data; CRED, unpubl. data), Guam (Randall, 2003; D. Burdick, unpubl. data), Commonwealth of the Northern Mariana Islands, Baker Island (CRED, unpubl. data), Palmyra Atoll (Williams et al., 2008b), and Kingman Reef (CRED, unpubl. data).

Within federally protected waters, *Turbinaria reniformis* has been recorded from the following areas:

- Pacific Remote Islands Marine National Monument (Baker, Palmyra, Kingman)
- National Park of American Samoa, Ofu Island unit
- Fagatele Bay National Marine Sanctuary, Tutuila
- Rose Atoll Marine National Monument

## Habitat

**Habitat:** *Turbinaria reniformis* has been reported to occupy shallow protected waters with some turbidity (Veron, 2000). The species can live on forereef slopes and can prevail in clear water as well but usually not in areas of heavy wave action.

**Depth range:** The depth range of *Turbinaria reniformis* has been recorded as 0 m–40 m. Sheppard and Sheppard (1991) found *Turbinaria reniformis* to occur commonly “at the base of reef slopes at 10 m or deeper.”

## Abundance

*Turbinaria reniformis* can be locally dominant and form massive and extensive stands, especially in protected shallow turbid waters.

## Life History

*Turbinaria reniformis* is a gonochoric broadcast spawner, with a 1:1 sex ratio reported from Magnetic Island on the central Great Barrier Reef (Babcock et al., 1994; Willis, 1987; Willis et al., 1985). The minimum size and estimate age at first reproduction have not been determined for this species. However, for the congener *Turbinaria mesenterina*, the minimum size at first reproduction is 12 to 16 cm, with an estimated age of 4 years (Willis, 1987). Planula larvae do not contain zooxanthellae that can supplement maternal provisioning with energy sources provided by their photosynthesis (Baird et al., 2009).

## Threats

**Thermal stress:** Bleaching in *Turbinaria* varies among regions. The study by Marshall and Baird (2000) showed *Turbinaria* to be the most resistant to bleaching when responding to high seawater temperatures than any of the other 39 generic groups of scleractinians tested, although *Turbinaria reniformis* in the same region can bleach quickly (Jones, 2008). *Turbinaria* were moderately vulnerable to bleaching in the western Indian Ocean from 1998 to 2005 (McClanahan et al., 2007), but that varied within that region—the genus bleached more in Mauritius than Kenya in 2004 (McClanahan et al., 2005a) and was one of the genera most resistant to bleaching in South Africa (Floros et al., 2004). Congeneric species had occasionally high bleaching and mortality in Palau in 1997–1998 (Bruno et al., 2001). It may be that some of the mixed bleaching response is whether the stress is temperature- or light-induced, as repeated exposure to high irradiance significantly decreases the energy budget in *Turbinaria* (Hoogenboom et al., 2006). Alternatively, spatial differences in bleaching could be attributed to symbiont presence, as *Turbinaria* can host either Clade C or Clade D zooxanthellae (LaJeunesse et al., 2003; Ulstrup et al., 2006). *Turbinaria reniformis* also shows the potential to reduce bleaching vulnerability through increased feeding rates (Ferrier-Pagès et al., 2010).

**Acidification:** *Turbinaria reniformis* appears to show a lower percent change in calcification when pCO<sub>2</sub> is doubled and tripled compared to the other genera of scleractinians experimentally tested (Kleypas et al., 2006). *Turbinaria reniformis* showed 13% reduction in growth in low-carbonate waters, but had no significant changes in skeletal microstructures (Marubini et al., 2003). We might predict that this is a generic characteristic. However, most corals studied have shown negative relationships between acidification and growth (Table 3.2.2) and acidification is likely to contribute to reef destruction in the future (Hoegh-Guldberg et al., 2007; Silverman et al., 2009). While ocean acidification has not been demonstrated to have caused appreciable declines in coral populations so far, the BRT considers it to be a significant threat to corals by 2100.

**Disease:** A white syndrome disease has affected *Turbinaria* in Australia since 2000; elevated temperatures appear to significantly increase tissue loss (Dalton et al., 2010). Ample evidence indicate that diseases can have devastating regional effects on individual coral species (e.g., Aronson and Precht, 2001; Bruckner and Hill, 2009) and evidence show that these effects are occurring in more taxa and at a broader geographic scale (Green and Bruckner, 2000; Sutherland et al., 2004).

**Predation:** Adult colonies of *Turbinaria* spp. are almost never eaten by crown-of-thorns seastars (Birkeland and Lucas, 1990). *Turbinaria* are not thought to be eaten by *Phestilla sibogae* (Ritson-Williams et al., 2003), but recent evidence suggests that *Phestilla* can both feed on *Turbinaria* as well as infect it with disease (Dalton and Godwin, 2006).

**Land-based sources of pollution (LBSP):** *Turbinaria* spp. can be dominant in turbid waters. For *Turbinaria reniformis*, Sheppard and Sheppard (1991) state that “It coexists with *Turbinaria mesenterina* and is often found in sedimented conditions.” Its congener *Turbinaria mesenteria* maintains photosynthetic and growth rates even under highly turbid conditions (Sofonia and Anthony, 2008), and accumulates significant energy reserves (Anthony, 2006). As a genus, *Turbinaria* are efficient sediment-rejecters (Stafford-Smith and Ormond, 1992) but have been observed to incur partial mortality from sediment during dredging events (Blakeway, 2005). *Turbinaria* adopt funnel-shaped morphologies in turbid environments that tend to localize sediment effects to small portions of the colony (Riegl et al., 1996).

*Turbinaria reniformis* appear to tolerate low-salinity events, as it survived with little damage the 1991 cyclone floodwaters in the Keppel Islands (Van Woesik et al., 1995). LBSP-related stresses (nutrients, sediment, toxins, and salinity) often act in concert rather than individually and are influenced by other biological (e.g., herbivory) and hydrological factors. Collectively, LBSP stresses are unlikely to produce extinction at a global scale; however, they may pose significant threats at local scales (particularly important for species with limited range) and reduce the resilience of corals to bleaching (Carilli et al., 2009a; Wooldridge, 2009b).

**Collection/Trade:** According to CITES records, *Turbinaria* spp. are one of the top 10 genera imported into the USA. Between 1997 and 2001, more than 63,400 specimens were imported (Wabnitz, 2003) and between 2000 and 2008 around 370,000 pieces (between 30,000 and 50,000 per year) were reportedly exported from Indonesia that appears to be the main exporting country of *Turbinaria* spp (CITES, 2010).

## Risk Assessment

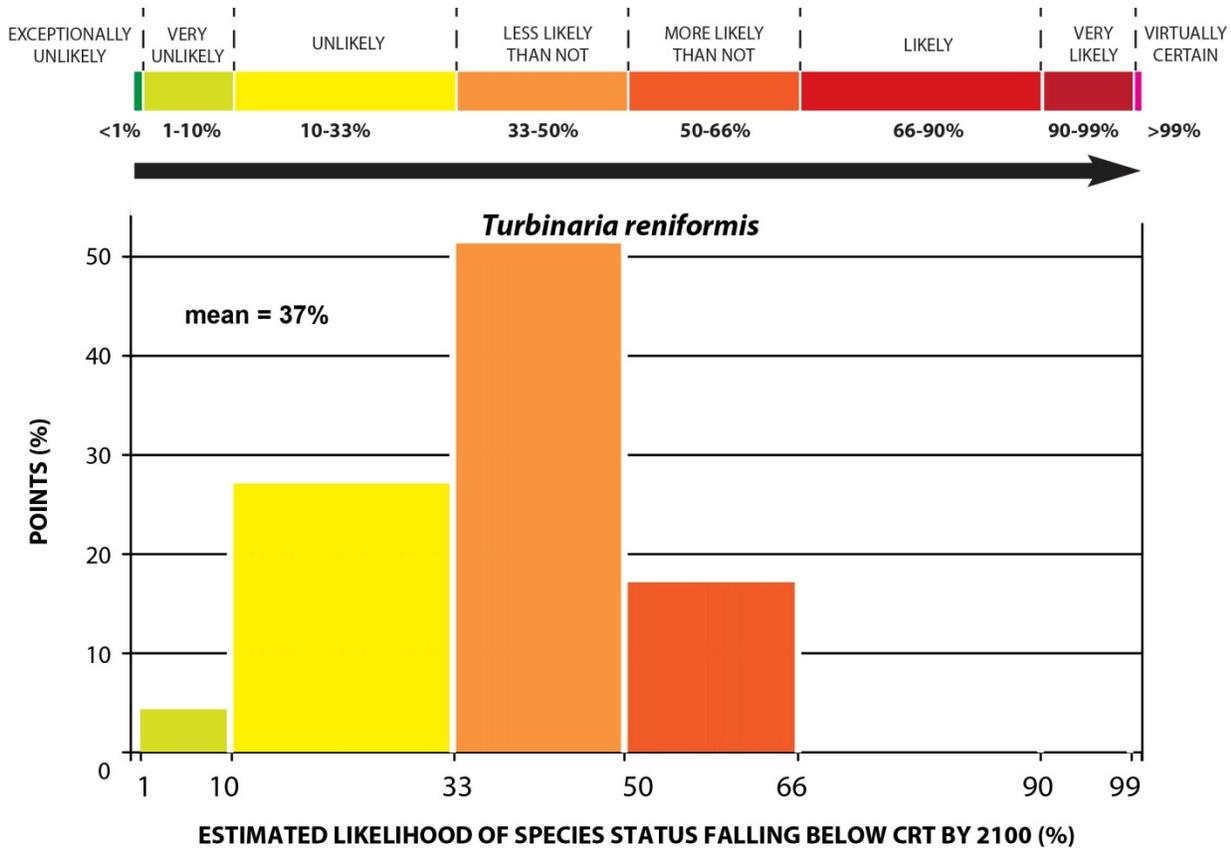


Figure 7.24.12. Distribution of points to estimate the likelihood that the status of *Turbinaria reniformis* falls below the Critical Risk Threshold (the species is of such low abundance, or so spatially fragmented, or at such reduced diversity that extinction is extremely likely) by 2100.

Factors that increase the potential extinction risk (higher likelihood of falling below the Critical Risk Threshold) for *Turbinaria reniformis* include susceptibility to disease and harvesting. They seem susceptible to disease at high latitudes in Australia. The aquarium trade appears to be the most immediate threat to populations of *Turbinaria*. Factors that reduce potential extinction risk (decrease the likelihood of falling below the Critical Risk Threshold) are that *Turbinaria reniformis* can be dominant in turbid waters, is remarkably tolerant to seawater warming, low salinity events, lower pH, and predation, and is broadly distributed both latitudinally and longitudinally in the Indo-Pacific. Wide distribution is considered to lower extinction risk by making it more likely a species will be able to escape the impacts of threats and catastrophes in at least some locations.

The overall likelihood that *Turbinaria reniformis* will fall below the Critical Risk Threshold by 2100 was estimated to be in the “less likely than not” risk category with a mean likelihood of 37% and a standard error (SE) of 10% (Fig. 7.24.12). This SE was calculated by taking the standard deviation of the seven mean voting scores of the BRT members and shows the coherence among the BRT. The uncertainty of the BRT is reflected in the range of votes of 1%–66% (Fig. 7.24.12) and the average range of likelihood estimates of the seven BRT voters (45%). The overall wide range of votes reflects the uncertainty among BRT members inherent in the lack of adequate ecological and demographic information for *Turbinaria reniformis*.

#### 7.24.4 *Turbinaria stellulata* Lamarck, 1816



Figure 7.24.13. Colonies of *Turbinaria stellulata* from (Veron and Stafford-Smith, 2002).

#### Characteristics

Colonies of *Turbinaria stellulata* are usually encrusting (two illustrations on the left) but can sometimes form large massive dome-shaped colonies (illustration to the right). *Turbinaria stellulata* can be easily distinguished from the more typical *Turbinaria* species that tend to form large lettuce-like assemblages of plates (Veron, 2000). Colonies are usually brown or green in color, but as for most corals, there are a variety of possibilities.

#### Taxonomy

**Taxonomic issues:** None. The genus *Turbinaria* is quite distinct and is not confused with other genera. The species are usually quite distinguishable, especially when seen together.

**Family:** Dendrophylliidae.

**Evolutionary and geologic history:** *Turbinaria* originated in the Tethys Sea in southern Europe in the Oligocene Epoch (Wells and Moore, 1956). It went extinct in the Atlantic (Caribbean), but it still occurs across the Indian and Pacific Oceans.

#### Global Distribution

*Turbinaria stellulata* has become very broadly distributed both longitudinally (from east Africa and the Red Sea to eastern central Pacific) and latitudinally (from southern Africa and the Great Barrier Reef to Japan).

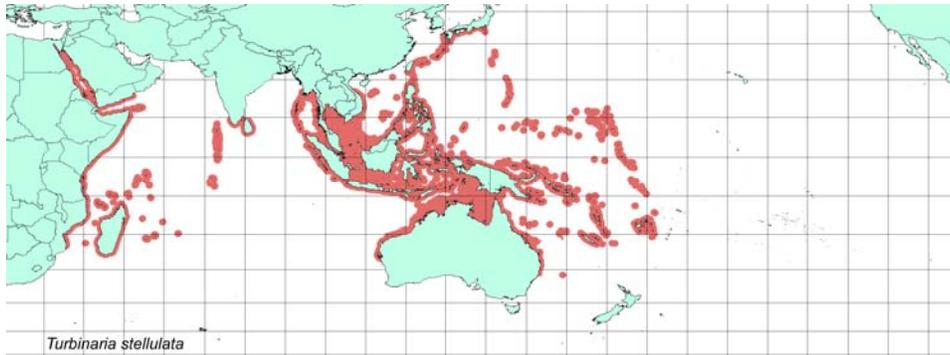


Figure 7.24.14. *Turbinaria stellulata* distribution from IUCN copied from <http://www.iucnredlist.org>.

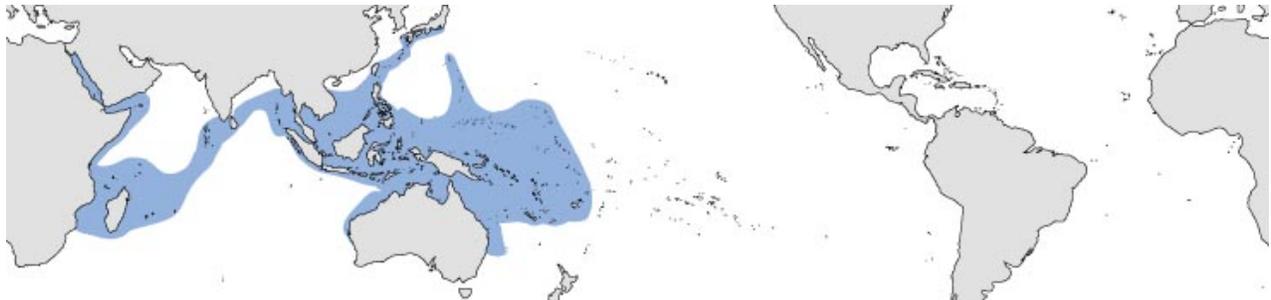


Figure 7.24.15. *Turbinaria stellulata* distribution from Veron (2000).

## U.S. Distribution

*Turbinaria stellulata* are found in American Samoa, the Marshall Islands, Palau, the southern Marianas and the Northern Marianas (Randall, 1995).

A search of published and unpublished records of occurrence in U.S. waters indicates *Turbinaria stellulata* has been reported from Tutuila, Ofu-Olosega, Rose Atoll, and South Bank in American Samoa (Maragos et al., 1994; Lovell and McLardy 2008; National Park Service, 2009; Kenyon et al., 2010a; CRED, unpubl. data), Guam (Randall, 2003; D. Burdick, unpubl. data), CNMI (CRED, unpubl.), Palmyra Atoll (Williams et al., 2008b), and Kingman Reef (CRED, unpubl. data).

Within federally protected waters, *Turbinaria stellulata* has been recorded from the following areas:

- Pacific Remote Islands Marine National Monument (Palmyra, Kingman)
- National Park of American Samoa, Ofu Island unit
- Rose Atoll Marine National Monument
- Marianas Trench Marine National Monument (Asuncion)

## Habitat

**Habitat:** Unlike *Turbinaria mesenteria*, *Turbinaria reniformis* and *Turbinaria peltata*, *Turbinaria stellulata* is generally found in clear water and is not often found in turbid waters (Veron, 2000).

**Depth range:** The depth range of *Turbinaria stellulata* is unknown.

## Abundance

*Turbinaria stellulata* has been reported as usually uncommon (Veron, 2000) or as generally scattered and occasional. It does not form massive and extensive stands as *Turbinaria mesenterina*, *Turbinaria reniformis* and *Turbinaria peltata* sometimes do.

## Life History

The reproductive characteristics of *Turbinaria stellulata* have not been determined. However, three other species of *Turbinaria* all are gonochoric broadcast spawners, although a low frequency of hermaphroditism has been shown on the Great Barrier Reef in the congener *Turbinaria mesenterina* (Willis, 1987). The minimum size and estimate age at first reproduction have not been determined for this species, but for *Turbinaria mesenterina*, the minimum size at first reproduction is 12 cm to 16 cm, with an estimated age of 4 years (Willis, 1987). Larval longevity has not been determined in this genus.

## Threats

**Thermal stress:** Bleaching in *Turbinaria* varies among regions. The study by Marshall and Baird (2000) showed *Turbinaria* to be the most resistant to bleaching when responding to high seawater temperatures than any of the other 39 generic groups of scleractinians tested, though *Turbinaria reniformis* in the same region can bleach quickly (Jones, 2008). *Turbinaria* were moderately vulnerable to bleaching in the western Indian Ocean from 1998 to 2005 (McClanahan et al., 2007), but that varied within that region—the genus bleached more in Mauritius than Kenya in 2004 (McClanahan et al., 2005a) and was one of the genera most resistant to bleaching in South Africa (Floros et al., 2004). Congeneric species had occasionally high bleaching and mortality in Palau in 1997-1998 (Bruno et al., 2001). It may be that some of the mixed bleaching response is due to whether the stress is temperature- or light-induced, as repeated exposure to high irradiance significantly decreases the energy budget in *Turbinaria* (Hoogenboom et al., 2006). Alternatively, spatial differences in bleaching could be attributed to symbiont presence, as *Turbinaria* can host either Clade C or Clade D zooxanthellae (LaJeunesse et al., 2003; Ulstrup et al., 2006).

**Acidification:** *Turbinaria reniformis* appears to show a lower percent change in calcification when pCO<sub>2</sub> is doubled and tripled compared to the other genera of scleractinians experimentally tested (Kleypas et al., 2006). *Turbinaria reniformis* showed 13% reduction in growth in low-carbonate waters but had no significant changes in skeletal microstructures (Marubini et al., 2003). We might predict that this is a generic characteristic. However, most corals studied have shown negative relationships between acidification and growth (Table 3.2.2) and acidification is likely to contribute to reef destruction in the future (Hoegh-Guldberg et al., 2007; Silverman et al., 2009). While ocean acidification has not been demonstrated to have caused appreciable declines in coral populations so far, the BRT considers it to be a significant threat to corals by 2100.

**Disease:** A white syndrome disease has affected *Turbinaria* in Australia since 2000; elevated temperatures appear to significantly increase tissue loss (Dalton et al., 2010). Black lesions were also observed on *Turbinaria mesenterina* almost simultaneously with a bleaching event on the Great Barrier Reef (Jones et al., 2004). However, ample evidence indicate that diseases can have devastating regional impacts on individual coral species (e.g., Aronson and Precht, 2001; Bruckner and Hill, 2009) and evidence show that these impacts are occurring in more taxa and at a broader geographic scale (Green and Bruckner, 2000; Sutherland et al., 2004).

**Predation:** Adult colonies of *Turbinaria* spp. are almost never eaten by crown-of-thorns seastar (*Acanthaster planci*) (Birkeland and Lucas, 1990). *Turbinaria* are not thought to be eaten by *Phestilla sibogae* (Ritson-Williams et al., 2003), but recent evidence suggests that *Phestilla* can both feed on *Turbinaria* as well as infect it with disease (Dalton and Godwin, 2006).

**Land-based sources of pollution (LBSP):** Unlike *Turbinaria mesenteria*, *Turbinaria reniformis*, and *Turbinaria peltata*, *Turbinaria stellulata* tends to be found in clear water. *Turbinaria stellulata* can, however, be found in shaded conditions (Dinesen, 1983)—implying some ability to cope with reduced light levels, if not turbidity. *Turbinaria mesenteria* maintains photosynthetic and growth rates even under highly turbid conditions (Sofonia and Anthony, 2008) and accumulates significant energy reserves (Anthony, 2006). As a genus, *Turbinaria* are efficient sediment rejecters (Stafford-Smith and Ormond, 1992) but have been observed to incur partial mortality from sediment during dredging events (Blakeway, 2005). *Turbinaria* adopt funnel-shaped morphologies in turbid environments as a means of localizing sediment impacts to small portions of the colony (Riegl et al., 1996). However, this is unlikely to be a benefit for *Turbinaria stellulata*, which primarily adopts flattened morphologies.

*Turbinaria stellulata* appears to tolerate low-salinity events, as it survived with little damage the 1991 flood in the Keppel Islands (Van Woeseik et al., 1995). LBSP-related stresses (nutrients, sediment, toxins, and salinity) often act in concert rather than individually and are influenced by other biological (e.g., herbivory) and hydrological factors.

Collectively, LBSP stresses are unlikely to produce extinction at a global scale; however, they may pose significant threats at local scales (particularly important for species with limited range) and reduce the resilience of corals to bleaching (Carilli et al., 2009a; Wooldridge, 2009b).

**Collection/Trade:** According to CITES records, *Turbinaria* spp. are one of the top 10 genera imported into the USA. Between 1997 and 2001, over 63,400 specimens were imported and between 2000 and 2008 around 370,000 pieces (between 30,000 and 50,000 per year) were reportedly exported from Indonesia which appears to be the main exporting country of *Turbinaria* spp. (CITES, 2010). However, *Turbinaria stellulata* might not be as attractive for the aquarium or curio trade because it does not generally grow in plates or blades.

**Risk Assessment**

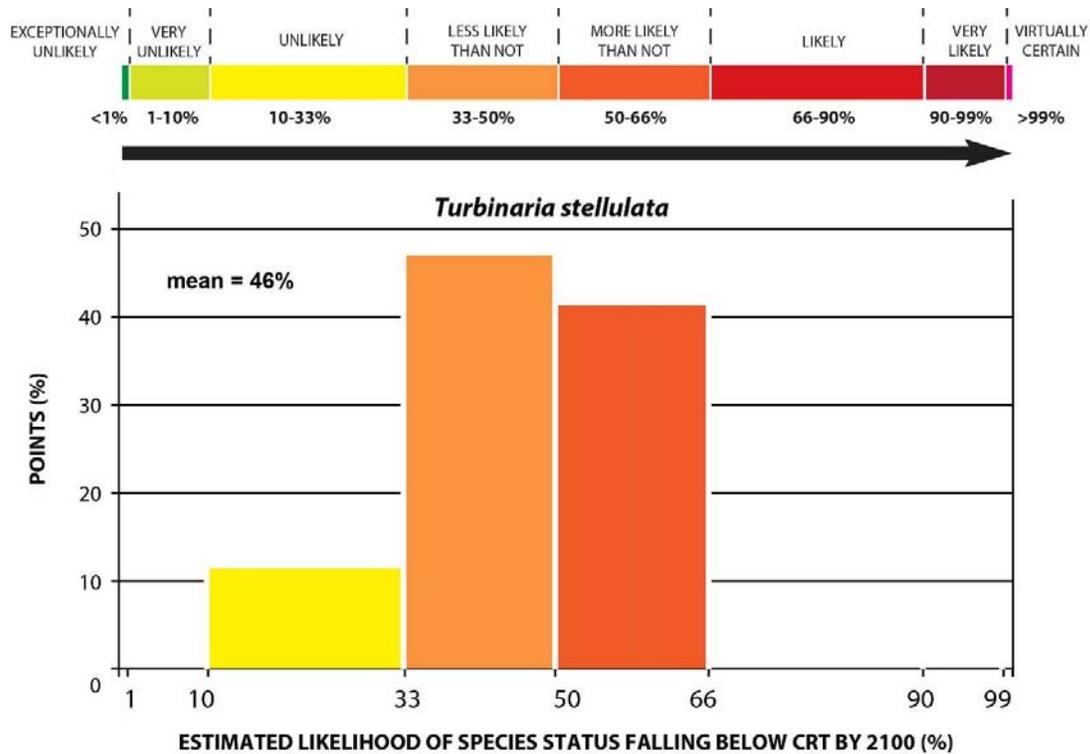


Figure 7.24.16. Distribution of points to estimate the likelihood that the status of *Turbinaria stellulata* falls below the Critical Risk Threshold (the species is of such low abundance, or so spatially fragmented, or at such reduced diversity that extinction is extremely likely) by 2100.

A factor that increases the potential extinction risk (higher likelihood of falling below the Critical Risk Threshold) for *Turbinaria stellulata* includes disease. Corals of the genus *Turbinaria* seem susceptible to disease at high latitudes in Australia. Factors that reduce potential extinction risk (decrease the likelihood of falling below the Critical Risk Threshold) for *Turbinaria stellulata* are tolerance to seawater warming, low salinity events, lower pH, and predation, and a broad geographic distribution both latitudinally and longitudinally in the Indo-Pacific. Wide distribution is considered to lower extinction risk by making it more likely a species will be able to escape the impacts of threats and catastrophes in at least some locations. *Turbinaria stellulata* has a higher risk than its congeners due to its relative intolerance of turbid waters.

The overall likelihood that *Turbinaria stellulata* will fall below the Critical Risk Threshold by 2100 was estimated to be in the “less likely than not” risk category with a mean likelihood of 46% and a standard error (SE) of 6% (Fig. 7.24.16). This SE was calculated by taking the standard deviation of the seven mean voting scores of the BRT members and shows the coherence among the BRT. The uncertainty of the BRT is reflected in the range of votes of 1%–66% (Fig. 7.24.16) and the average range of likelihood estimates of the seven BRT voters (41%). The overall wide range of votes reflects the uncertainty among BRT members inherent in the lack of adequate ecological and demographic information for *Turbinaria stellulata*.