Queen Conch Consultation Framework
NOAA Fisheries Southeast Region

September 2024

Figure 1: Juvenile queen conch in seagrass (Photo: Jennifer Doerr, NOAA-SEFSC).

Purpose and Scope

To inform the Southeast Region's (SERO) Endangered Species Act (ESA) Section 7 consultation activities for queen conch (*Aliger gigas*, formerly *Strombus gigas,* and *Lobatus gigas*), this document consolidates, summarizes, and interprets the best available information obtained through the listing process and subsequent research by federal, state, and university partners. This collection of information provides ESA Section 7 assistance and identifies actions that can be taken early in the consultation process to promote species conservation and improve overall consultation efficiency for the action agency. This document synthesizes information and should be considered a job aid, used as general guidance only.

Queen conch are listed as a threatened species under the ESA (89 FR 11208, February 14, 2024), meaning that they are not presently at risk of extinction, but are likely to become so in the foreseeable future, throughout all or a significant portion of its range. Queen conch occur in the United States (U.S.), Caribbean Sea, Mexico, and Central and South America in marine waters at depths up to 61 m (200 ft), primarily occurring in waters less than 30 m (98 ft) deep. Within the Southeast Region of the U.S., queen conch are most likely to occur in marine waters [i.e., projects occurring below mean high water (MHW), and salinities above 20 ppt], excluding man-made canals and channels, swash zones, and ocean dredged material disposal sites (ODMDS) in the following locations:

- Within the 61 m (200 ft) isobaths: (1) Southeast Florida and the Atlantic Ocean side of the Florida Keys from St. Lucie Inlet south to Key West; (2) Marquesas Keys; (3) Dry

Tortugas; (4) Puerto Rico; (5) U.S. Virgin Islands (USVI); (6) Navassa Island; and (7) Flower Garden Banks National Marine Sanctuary.
- Within the 10 m (33 ft) isobaths on the Gulf of Mexico side of the Florida Keys from the Seven Mile Bridge (west end of Marathon) south to Key West.

U.S. waters are estimated to contain 0.61% of the total adult population (Puerto Rico: 0.19%, Florida: 0.22%, USVI: 0.19%) and 6.94% of the available conch habitat (Puerto Rico: 3.25%, Florida: 3.25%, USVI: 0.44% (Horn et al. 2022). Because queen conch require certain densities to effectively breed, effective management strategies for queen conch should aim to protect high-density reproductive aggregations and breeding habitats. Populations with densities above 100 adult conch/ha are considered to support reproductive activity resulting in population growth. Although reproductively viable populations in the U.S. jurisdiction are limited, they serve as an important node for connectivity and the broader recovery of the species, particularly in Puerto Rico and the U.S. Virgin Islands. Current models suggest that Florida populations are the product of upstream larval supply and self-recruitment (Vaz et al. 2022).

Status Overview

- Queen conch are a slow-moving gastropod snail that occurs in seagrass beds, sand plains, and coral reefs; their distribution is believed to be limited by the availability of algae and native seagrass detritus.
- Queen conch are highly sought after for their meat, shell, and pearls.
- The most significant threats to queen conch are overutilization (through commercial; artisanal; and illegal, unreported, or unregulated fishing) and inadequate fishery regulatory mechanisms to reverse this trend in the foreseeable future (i.e., 2052).
- Increased ocean temperatures and acidification attributable to climate change represent significant threats to queen conch reproduction and shell calcification in the foreseeable future (i.e., 2100).
- Density estimates suggest most queen conch populations are below the minimum thresholds necessary for reproduction.

Figure 2: Conch have long eye stalks that move independently and a tube like mouth called a proboscis that it can pull into its shell if threatened (Photo: Jennifer Doerr, NOAA-SEFSC).

Species Life History

*Aliger gigas (*Linnaeus 1758), commonly known as the queen conch, is a species of large sea snail, a marine gastropod mollusk in the family of true conches (Strombidae), in the phylum Mollusca. Queen conch are characterized by a large, heavy, whorl-shaped shell with multiple short spines at the apex, a brown and horny operculum (a plate that closes the opening of the shell when the animal is retracted), and a pink interior of the shell lip. Adult queen conch shells can grow to 12 inches in length and weigh up to 5 pounds (2.3 kg) (Figure 3).

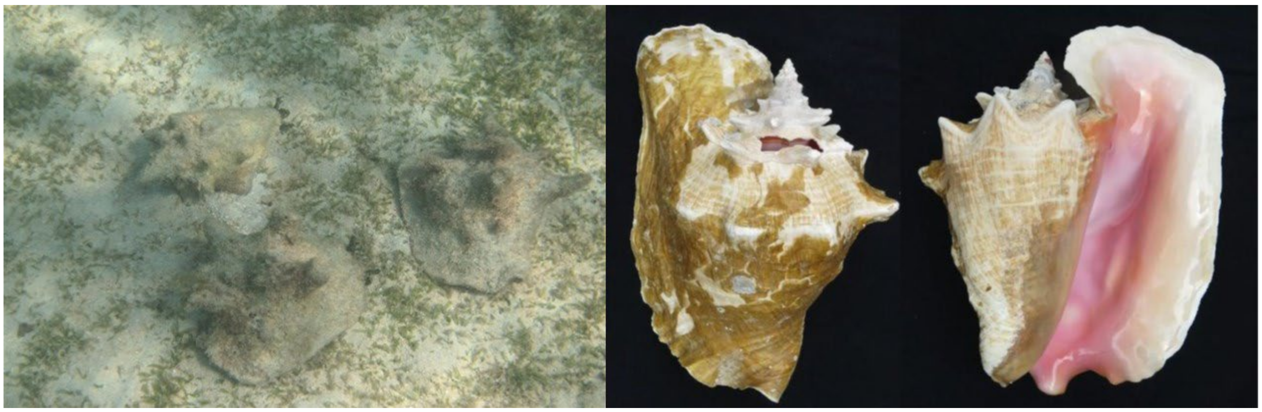

Figure 3: The outside of the queen conch shell becomes covered by an organic periostracum ("around the shell") layer and as the queen conch matures it becomes much darker than the natural color of the shell. This outer layer is often encrusted with algae, corals, and other benthic organisms (Photo: Jennifer Doerr, NOAA-SEFSC).

Age and Growth

Queen conch are a long-lived species, reaching 25 to 30 years old, and believed to reach sexual maturity around 3.5 to 4 years of age. They reach maximum shell length before sexual maturation; thereafter the shell grows only in thickness. Size at maturity can vary depending on environmental conditions. The growth rate and shell morphology of queen conch can vary depending on sex, depth, latitude, food availability, age class, and habitat type. Females on average grow more quickly, grow to a larger size, and have greater weight than males (Appeldoorn 1988a). Queen conch exhibit periods of seasonal growth associated with water temperature and food availability. Summer growth rates are greater than winter growth rates (Stoner and Ray 1993).

Figure 4: Queen conch size and growth (Photo: Jennifer Doerr, NOAA-SEFSC).

Range and Distribution

The queen conch occurs in the Caribbean Sea, the Gulf of Mexico, southern Florida, and around Bermuda (Figure 5) and includes the following jurisdictions: Anguilla, Antigua and Barbuda, Aruba, Barbados, Bahamas, Belize, Bermuda, Caribbean Netherlands, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, French West Indies, Grenada, Haiti, Honduras, Jamaica, Mexico, Montserrat, Nicaragua, Panama, Puerto Rico, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Trinidad and Tobago, Turks and Caicos, and U.S. (Florida, Puerto Rico, USVI, Navassa, Flower Garden Banks National Marine Sanctuary), British Virgin Islands, and Venezuela (Theile 2001).

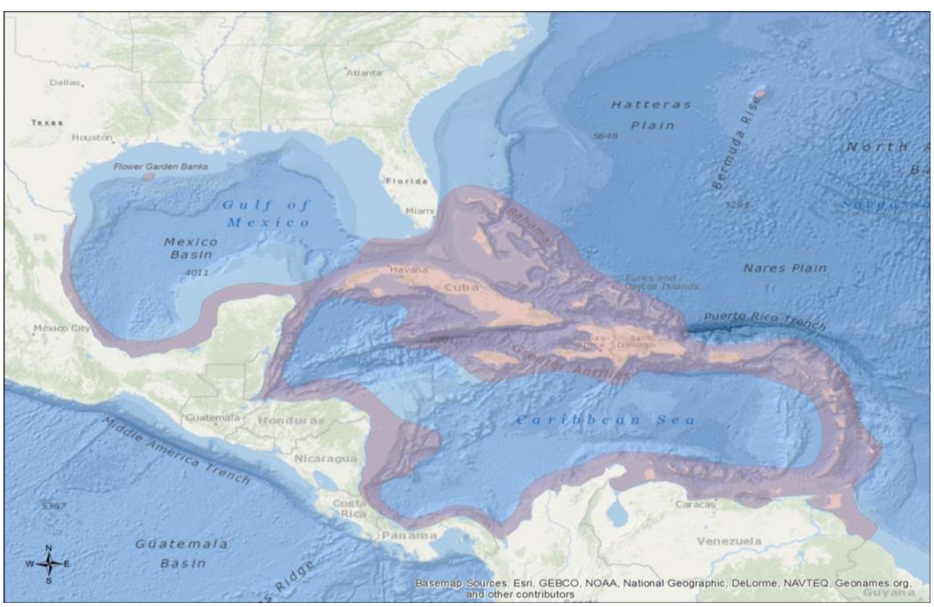

Figure 5: Map of the geographic distribution of queen conch.

U.S. waters are estimated to contain 0.61% of the total contemporary adult conch population abundance and 6.94% of the available conch habitat. The total adult queen conch estimated abundance (i.e., the sum of median estimated abundance across all jurisdictions) was 743 million individuals, this translates to approximately 4.5 million individuals in U.S. waters. This estimate is highly uncertain and based on data of varying quantity and quality by jurisdiction (Horn et al. 2022).

Queen conch occur in different habitat types including seagrass and algae beds, sand flats, and rubble areas from a few cm deep to depths generally less than 61 m. Adult distributions are heavily influenced by food availability and fishing pressure. In unexploited areas, they are most common in shallow marine waters less than 30 m. Adult queen conch prefer sandy algal flats but are also found on gravel, coral rubble, smooth hard coral, and beach rock bottom, while juveniles are primarily associated with seagrass beds (Doerr and Hill 2018; Glazer and Kidney 2004; Stoner 2003).

Diet

Larval conch feed on phytoplankton (Davis 2005). The primary diet of juvenile conch consists of native seagrass detritus and red and green macroalgae, primarily *Laurencia* spp. and *Batophora oerstedii* (Randall 1964; Serviere-Zaragoza et al. 2009; Stoner and Sandt 1992; Stoner and Waite 1991). Juveniles are thought to feed on organic material in the sediment, such as benthic diatoms and particulate organic matter and cyanobacteria (Serviere-Zaragoza et al. 2009; Stoner et al. 1995; Stoner and Waite 1991), macroalgae in seagrass beds, and epiphytes that live on the seagrass (Stoner 1989b; Stoner and Waite 1991). Adult conch feed on different types of filamentous algae (Creswell 1994; Ray and Stoner 1995).The presence of the green algae, *B. oerstedii*, in The Bahamas is correlated to areas of higher conch densities (Stoner and Lally 1994) and even caused an aggregation to shift orientation (Stoner and Ray 1993).

Life Stages and Habitat Use

Eggs, Larvae, and Juveniles

Egg laying takes 24 to 36 hours, with each egg mass containing from 150,000 to 1,649,000 eggs in a long continuous egg-filled and compact crescent shape. (Appeldoorn 1993; Appeldoorn 2020; Berg Jr. and Olsen 1989; D'Asaro 1965; Delgado and Glazer 2020; Mianmanus 1988; Randall 1964; Robertson 1959; Weil and Laughlin 1984). The number of egg masses produced per female is highly variable and ranges between 1 and 25 egg masses per female per season (Appeldoorn 1993; Berg Jr. and Olsen 1989; Davis and Hesse 1983; Davis et al. 1984; Weil and Laughlin 1984). Upon hatching, the veligers (larvae) drift in the upper water column for up to 30 days (Paris et al. 2008; Posada and Appeldoorn 1994; Stoner 2003; Stoner and Davis 1997), then metamorphose into benthic infaunal (i.e., living in the substrate) juveniles, where they bury in sediments, typically adjacent to seagrass habitats in response to trophic cues (Davis 2005). Juveniles emerge from the sediment about a year later (Stoner 1989a) at around 60 mm shell

length. When these epifaunal (e.g., above the substrate) juvenile conch first emerge, they move into nearby seagrass beds, where densities can be as high as 200–2000 conch/ha.
Most conch nursery areas occur primarily in back reef areas (i.e., shallow sheltered areas, lagoons, behind emergent reefs or cays) of medium seagrass density, depths between 2 to 4 m, or 6 to 13 ft (Jones and Stoner 1997), with strong tidal currents (at least 50 cm/s; (Stoner 1989b), and frequent tidal water exchanges (Stoner et al. 1996; Stoner and Waite 1991). Seagrass is thought to provide both nutrition and protection from predators (Ray and Stoner 1995; Stoner and Davis 2010). The structure of the seagrass beds decreases the risk of predation (Ray and Stoner 1995), which is very high for juveniles (Appeldoorn 1988c; Posada et al. 1997; Stoner et al. 2019; Stoner and Glazer 1998).

Although juvenile queen conch are primarily associated with native seagrass, such as *Thalassia testudinum*, in their range in the Caribbean and the southern Gulf of Mexico (Boman et al. 2019), they can occur in a variety of habitat types. In the USVI, juvenile queen conch were more abundant in shallow coral-rubble environments than on bare sand and seagrass beds (Randall 1964). In Puerto Rico, Torres Rosado (1987) reported higher numbers of conch in coral rubble compared with sand, seagrass, and hard bottom (Torres Rosado 1987). In Florida, juveniles are found in reef rubble, algae-covered hard bottom, and secondarily in mixed beds of algae and seagrass, depending upon general location (Glazer and Berg Jr. 1994). In St. Croix, USVI, densities of juvenile and adult queen conch were the highest in habitats characterized as 50–90% and 10–50% patchy seagrass, respectively (Doerr and Hill 2013; Doerr and Hill 2018; Stoner and Waite 1991).

Adults

Adult distributions are heavily influenced by food availability and fishing pressure. They prefer sandy algal flats but are also found on gravel, coral rubble, smooth hard coral, patchy seagrass, and beach rock bottom (Acosta 2001; Doerr and Hill 2018; Glazer and Kidney 2004; Stoner 2003; Stoner and Davis 2010). Adult queen conch are rarely, if ever, found on soft bottoms composed of silt and/or mud (including man-made canals), or in areas with high coral cover (Acosta 2006). Adult conch are found in shallow, clear water of oceanic or near-oceanic salinities (rarely in low salinities) at depths generally less than 61 m, and, in less exploited areas, are most often found in waters less than 30 m (McCarthy 2007).

The movements of adult conch are associated with factors like changes in temperature, food availability, and predation. The average home range size for an individual queen conch is variable and has been measured at 5.98 ha in Florida (Glazer et al. 2003). Also, it was found that there were no significant differences in movement rate, site fidelity, or size of home range between adult males and females (Glazer et al. 2003). However, home range in queen conch is highly variable throughout its range and movement patterns and speeds may differ as well (Farmer and Doerr 2022). Few studies have been conducted to definitively demonstrate differences in movement patterns and speeds throughout the range of the queen conch, but the studies that have been conducted show different movement patterns and speeds between

Florida and St. Croix, in the Virgin Islands (Doerr and Hill 2013; Doerr and Hill 2018; Glazer et al. 2003). The factors that affect these differences are unclear, but may be a result of low sample size, differences in conch size, or different environmental cues that initiate movements, such as temperature or spawning migrations.

Daily movement speeds have been estimated through acoustic telemetry. Adults move at varying speeds throughout the year with movement rates increasing during seasonal migrations and slowing during foraging activities or upon reaching mating aggregations. Queen conch typically move slowly (<5 m/d; (Doerr and Hill 2018; Glazer et al. 2003)) but can move significantly faster: 11.36±0.24 m/d (mean±sd), and maximum observed of 21.24 m/d; (Doerr and Hill 2018)) when traveling to aggregations. Queen conch move at a greater speed during the summer, which may be due to the increased metabolic activity associated with warmer waters and increased movement related to their reproductive season (i.e., males searching for mates and females moving into egg-laying habitat (Glazer et al. 2003)).

Reproduction

Spawning Season

Queen conch have a protracted spawning season of 4 to 9 months, with peak spawning during warmer months (Table 1). Generally, queen conch in the Southeast Region have the ability to spawn year round, but peak spawning occurs during a narrower window during the year, as presented below in Table 1 (Stoner and Appeldoorn 2022). They reproduce through internal fertilization, meaning individuals must be in contact to mate. Seasonal movements are usually associated with the initiation of the reproductive season. Adult conch can move from offshore feeding areas in the winter to summer spawning grounds in shallow, inshore sand habitats; and from seagrass to sand-algal flats with the onset of winter (Hesse 1979). In locations where adult conch are abundant, migrations culminate in the formation of reproductive aggregations. These aggregations generally form in the same locations each year (Glazer and Kidney 2004; Marshak et al. 2006; Posada et al. 1997) and are dominated by older individuals that produce large, viable egg masses (Berg Jr. et al. 1992).

The duration and intensity of the spawning season are mediated by temperature, photoperiod, and weather events, and vary extensively throughout the queen conch’s range (Table 1). Generally, reproductive activity begins earlier and extends later into the year with decreasing latitude; extending from May to September in Florida (D'Asaro 1965), May to November in Puerto Rico (Appeldoorn 1985), and February through November in the U.S. Virgin Islands (Coulston et al. 1987; Randall 1964).

In the Florida Keys, adult aggregations are relatively persistent throughout the year, although reproductive activity does not occur year-round (Glazer and Kidney 2004). Queen conch found in the deep waters near Puerto Rico are geographically isolated from nearshore, shallow habitats and remain offshore during the spawning season (García-Sais et al. 2012).

Table 1: Reproductive/spawning cycle of queen conch, from visual surveys. Colors indicate relative level of reproductive activity (white = none, light gray = low, medium gray = medium, dark gray = high or peak activity). (Modified from Horn et al. 2022).

Time of Year												Duration (month)	Area	Original Source
J	F	M	A	M	J	J	A	S	O	N	D			
												4.5	Florida	(D'Asaro 1965)
												7	Florida	(Davis et al. 1984)
												6	Florida	(Delgado and Glazer 2020)
												6	Puerto Rico	(Appeldoorn 1988b)
												5	Puerto Rico	(Appeldoorn 1993)
												9	St. John (USVI)	(Randall 1964)
												9	St. Croix (USVI)	(Coulston et al. 1987)

Differences in spawning rates have been attributed to spawning site selection, population densities, and food selection and availability, among other factors. However, it is widely suspected that adult breeding population density is the most important factor to promote reproduction. Conch in low-density environments produced more abundant and larger egg masses and demonstrate a longer spawning season than conch in high-density environments. Variability in spawning activity may also be correlated to water temperature and weather conditions. Reproductive activity decreased with increasing water turbulence (Davis et al. 1984) and reproduction peaked with longer days. Reproductive inhibition has also been described for individuals that are exposed to contaminants (Spade et al. 2010). In particular, high concentrations of Tributyltin (TBT), a biocide previously used in antifouling paint and commonly found in water and sediment samples near marinas and shipping lanes (Chau et al. 1997), is known to cause imposex in conch (Titley-O'Neal et al. 2011). Imposex is a condition in which male external genitalia are present in the female conch, and female reproductive capacity is greatly reduced.

While seasonal temperature changes likely initiate spawning cues in queen conch, recent extreme warming events in Southern Florida are likely causing reproductive failure at shallow water aggregation locations in the Florida Keys (Florida Fish & Wildlife Conservation Commission, Public Comment, Nov. 7, 2022). These shallow-water aggregations are isolated from the deep-water aggregations by Hawk Channel, which runs parallel to the reef throughout the entire reef tract of the Florida Keys. Most nearshore populations in Florida show a complete lack of reproductive activity with reduced gonadal development (Delgado et al. 2004; Glazer and Quintero 1998). The shallow-water queen conch resume spawning activity if they are relocated to deep-water aggregation locations (Delgado et al. 2004). There are only two known reproductively active shallow-water aggregations in Florida. While neither aggregation is completely mapped yet, an aggregation exists at Port Everglades, directly to the south of the shipping channel, while the second is an aggregation next to the St. Lucie Inlet, primarily located in the Intracoastal Waterway.

There are a limited number of reproductively viable aggregation sites within the U.S. territories (Figures 6-8). These locations play a significant role in the recovery potential of the species. For example, Puerto Rico's spawning site at the Abrir La Sierra reef, located in the southeast of the Mona Passage (García-Sais et al. 2012), connects populations in Puerto Rico and the Dominican Republic (Vaz et al. 2022). The aggregation south of Port Everglades is comprised of at least 8,000 individuals, and potentially up to 40,000 individuals, corresponding to densities averaging 173 conch/ha and up to 700 conch/ha (J. Doerr, SEFSC, unpublished data) and may play a major role in sustaining nearshore Florida populations. This aggregation is second most northern documented spawning aggregations of queen conch in the world, and therefore may represent a population that is more robust than others to climate change. The aggregation is also thought to have important seeding potential for both the Florida Keys, and the nearby Bahamas archipelago (Vaz Pers. Comm.).

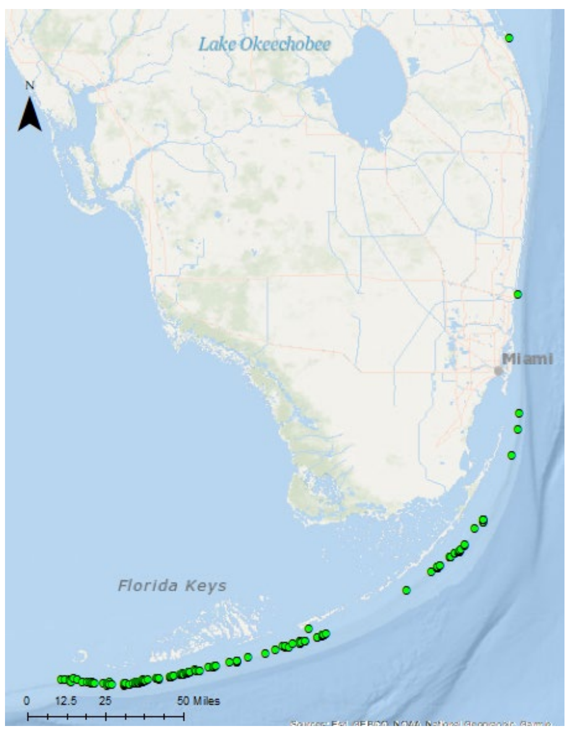

Figure 6: Aggregation locations for queen conch in the Florida Keys. Aggregations were defined as FWC survey sites with 10 or more individuals monitored, and limited to locations surveyed by FWC.

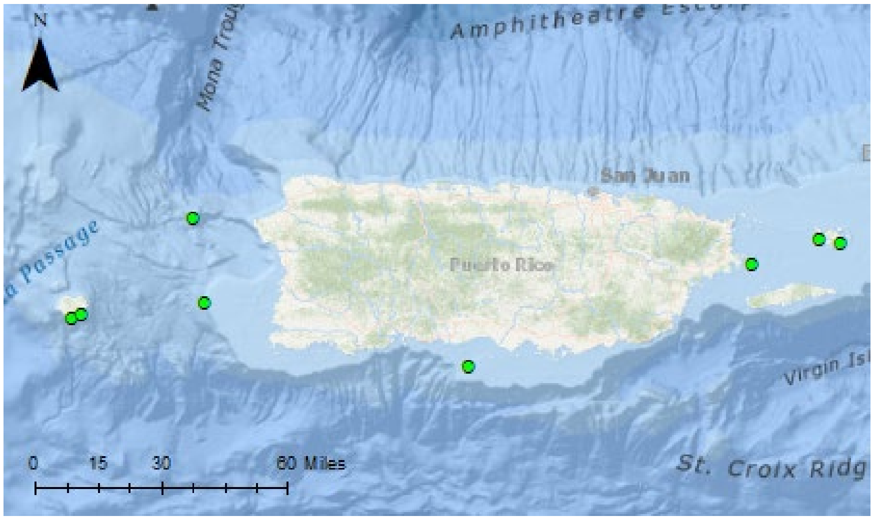

Figure 7: Known aggregation locations for queen conch in Puerto Rico, as determined by survey locations with densities of over 100 adult conch per hectare.

Figure 8: Known aggregation location for queen conch in the U.S. Virgin Islands, as determined by survey locations with densities of over 100 adult conch per hectare.

Depensatory Limitations on Reproduction

Depensatory mechanisms, or factors that can accelerate the decrease in the reproductive population, are a major factor limiting the recovery of overharvested queen conch populations (Appeldoorn 1995; Stoner et al. 2012a). Reproductive potential is primarily reduced by the removal of spawners from the population (Appeldoorn 1995). Observations suggest mating and egg-laying in queen conch are directly related to the density of mature adults (Stoner et al. 2011; Stoner et al. 2012b; Stoner and Ray-Culp 2000). In animals that aggregate to reproduce, low population densities can make it difficult or impossible to find a mate (Appeldoorn 1995; Erisman et al. 2017; Rossetto et al. 2015; Stephens and Sutherland 1999; Stoner and Ray-Culp 2000). Challenges associated with mate finding are likely exacerbated for slow-moving animals such as conch (Doerr and Hill 2013; Farmer and Doerr 2022; Glazer et al. 2003). This limitation translates directly into limited recovery because increased “search time” depletes energy and time resources, reducing the rate of gametogenesis and the overall reproductive potential of the population. Although delayed mate finding appears to be the primary driver behind reproductive failure, experiments (Gascoigne and Lipcius 2004) and simulations (Farmer and Doerr 2022) suggest delayed functional maturity at low density sites is required to fully explain declines in reproductive activity.

Due to the importance of adult spawning aggregation density, Horn et al. (2022) defined the following thresholds to determine the reproductive viability of queen conch populations throughout the greater Caribbean:

- Populations with densities above 100 adult conch/ ha are considered to be at a density that supports reproductive activity resulting in population growth.
- Populations with densities between 50–99 adult conch/ ha are considered to have reduced reproductive activity resulting in minimal population growth.
- Populations with densities below the 50 adult conch/ ha threshold are considered to be not reproductively active due to low adult encounter rates or mate finding. Fifty conch per hectare is largely recognized as an absolute minimum required to support mate-finding and thus reproduction.
- While these are general guidelines, density thresholds are location-specific and may differ among project areas, specifically in Florida where densities of over 204 conch/ha are thought to be needed for successful reproduction (Delgado and Glazer 2020).

The majority [69%; Horn et al. (2022)] of jurisdictions within the queen conch's range are characterized by populations with adult densities below reproductively viable thresholds (Figure 9). Adult densities in U.S. jurisdictions are presented in Table 2 below.

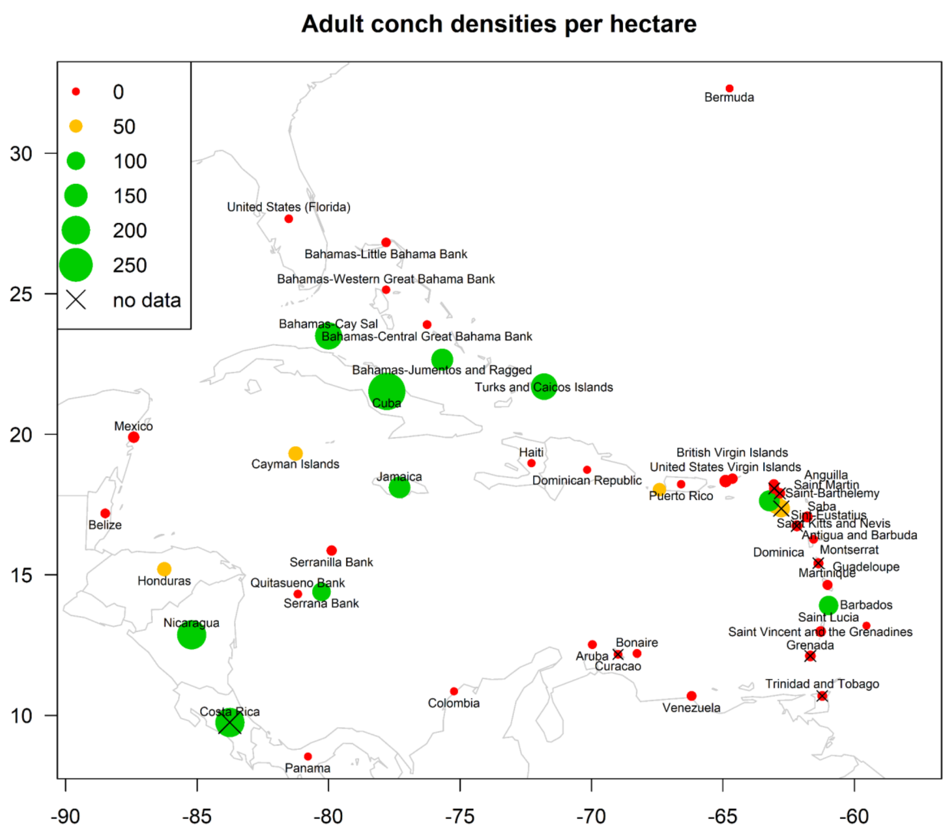

Figure 9: Data points are sized relative to densities; green symbols indicate conch populations with >100 adult conch/ha, gold symbols indicate 50-99.9 adult conch/ha, and red symbols indicate <50 adult conch/ha (Horn et al. 2022)..

Table 2: Adult conch density and habitat area estimates calculated by the Status Review Team from Horn et al. (2022).

Jurisdiction	**Lat**	**Long**	**Habitat (km^2)**	**Adult Density (/ha)**	**Data sources used to support the estimate**
Florida	27.7	-81.5	2372.3	7.0	Average from studies of non-aggregation sites from 2012 – 2019; cross-shelf densities from Glazer 2020 were derived by dividing total abundance estimates by statistical sampling domain
Puerto Rico	18.2	-66.6	2372.3	6.1	Derived distribution from sites in east, west, and south from 2001 – 2013; excluded unfished mesophotic site with higher density (reported separately)
Puerto Rico mesophotic reef	18	-67.4	NA	54.6	Unfished mesophotic site is only location where densities are over 20 conch/ha; reported separately
U.S. Virgin Islands	18.3	-64.9	323.5	44.5	Derived from all estimates from 3 islands; surveys done 2001 – 2011; most data are from St. Croix

Section 7 Considerations

This section provides information to assist biologists with section 7 consultations. This examination considered published scientific literature, as well as unpublished data provided by non-governmental, state, and federal agencies. The best available information indicates that queen conch are distributed throughout the wider Caribbean region from Venezuela in the south to the central east coast of Florida in the north. Queen conch are also present in the Flower Garden Banks National Marine Sanctuary. Within these areas, they exhibit a patchy distribution from the shoreline (MHW, excluding swash zones) out to depths of approximately 61 m (200 ft). Queen conch are sensitive to low salinities and dredged benthos and therefore do not occur in freshwater environments, such as rivers or lakes, and are very infrequently documented in man-made canals or on silt bottoms. Therefore it is not necessary to consider them within consultations that occur within primarily freshwater systems (i.e., $\leq$ 20 ppt), man-made canals, or where the entire benthos of the project area is comprised of silt. Please refer to the SERO Section 7 Mapper for more detailed information regarding where to consult on queen conch in the Southeast Region.

No Effect Determination

When making a “no effect” determination, it is not necessary to mention the species in the consultation. Below are common activities that could support an action agency’s “no effect” conclusion for queen conch.

Entanglement: Queen conch can experience entanglement, even lethal entanglement, in netting, especially when it is slack or loose. However, taut lines, thick lines, or chains that are unlikely to loop and tangle, and non-entangling barriers (e.g., turbidity curtains, oil booms) do not pose an entanglement risk to queen conch, and there are no reports of entanglement in turbidity curtains or in-water lines. Therefore, if the following project design criteria are used, we believe that there will be no routes of adverse effect from contact with or entanglement in the following construction materials:

- All in-water lines (e.g., mooring lines, rope, chain, and cable, including the lines to secure the turbidity curtains) must use the minimum amount of in-water line to safely perform their functions and remain under sufficient tension to avoid sagging and potentially forming loops of line on or near the seafloor.
- Turbidity curtains and in-water equipment must be placed in a manner that does not entrap species within the construction area.

Ocean noise: Very little is known about the effects of noise on queen conch. However, due to the minimal use of sound by the animal and the lack of developed auditory organs, acoustic impacts are not considered a route of adverse effect. Ensuring that queen conch are at least 12 m beyond the physical footprint of projects generating noise, or that the project uses a top to bottom turbidity curtain around the project footprint perimeter, is currently believed to be adequate to protect them from physical injury or behavioral disturbance.

Activities that do not impact the benthos: Other than a brief (≤30 days) pelagic larval phase, queen conch are entirely benthic animals throughout their life cycle. Therefore, activities of limited scale and duration that do not impact the benthos, such as surface or mid-water activities, are not considered to have a route of adverse effects to queen conch.

Activities that minimally impact the benthos: Projects with a footprint (i.e., all aspects of the project footprint, including areas that do not directly contact the benthos) of <5 m^2 and/or non-mechanical projects, using manual in-water work, are not considered to have a route of adverse effects to queen conch. Manually-conducted in-water work projects must ensure that divers and/or visibility conditions are such that workers can ensure no interactions with queen conch.

May Affect Determination (Not Likely to Adversely Affect [NLAA] or Likely to Adversely Affect [LAA]) for the Species

For proposed actions that may affect queen conch, the biologist must carefully analyze the effects of the proposed action to confirm whether a NLAA or LAA determination is most applicable (Table 3). An activity that is typically NLAA could be LAA for a different consultation if circumstances are significantly different or best-management practices or project design criteria are not incorporated.

Minimization Measures

Regardless of consultation type (i.e., formal or informal), a constructive dialog between NMFS and the action agency can shape the proposed action to minimize negative effects on conservation and recovery of the species. For example, the biologist can seek ways to incorporate mitigation measures and best practices, recommend different equipment, materials, or methods, or require monitoring and environmental windows to ensure the proposed action is carried out in the most careful and least impactful manner possible. Such minimization measures are required, as part of any non-jeopardy formal consultation (i.e., a LAA determination) under the Incidental Take Statement. In those instances, "Terms and Conditions" designed to monitor and minimize the impact of any such take on the species will be developed.

Best Management Practices for Reducing and Avoiding Effects to Queen Conch

Consider the following when including queen conch in the consultation:

- Require the use of the SERO Protected Species Construction Conditions, and the Queen Conch Survey, Construction Conditions, Relocation and Reporting Guidance, and other applicable project design criteria.
- Ensure projects minimize sedimentation, particularly fine grained.
- Ensure projects prevent debris from entering the environment.

Depending on the scope of the action and the number of conch that may be detected in a project area, NMFS should consider advising the action agency on additional considerations for queen conch relocation and the incorporation of environmental windows to minimize risk and probability of adverse effects, particularly with regards to queen conch spawning seasons. Action agencies should work with SERO to time their activities when risk is minimized (see Table 1) and enact conservation measures to reduce the level and duration of exposure to any routes of effect.

The likelihood of effects of an action on a listed species are a product of the likelihood of the action and the species co-occurring in space and time, the likelihood of the proposed action having an adverse effect on the species, and the duration and severity of that effect. The guidelines presented in the Queen Conch Survey, Construction Conditions, Relocation and Reporting Guidance, appropriate to minor, small scale (5–1000 m^2) actions denoted with an asterisk in Table 3, ensure adequate survey coverage of the action area, including a buffer derived from upper-limit daily movements in queen conch habitats, as well as relocation procedures for densities of queen conch that do not exceed the threshold needed for reproductive activity. The pre-construction and during-construction surveys are sufficient to ensure that the direct or indirect injury to conch is extremely unlikely to occur through visual determination that the project area is not active conch habitat or, or if conch are detected using the habitat, through verification that individual conch have not entered portions of the project area where injury may occur. When only a small number of conch – below densities of 10 adults/ha that indicate potential reproductive activity – are detected in surveys, the

Guidance includes procedures to allow the conch to leave the project area or to be carefully relocated, ensuring that direct or indirect injury from construction activities is extremely unlikely to occur. The relocation methods and handling procedures described in the Guidance were developed based on protocols that were used in various scientific studies that performed these same actions (Delgado et al. 2004; Delgado and Glazer 2007; Doerr and Hill 2013; Glazer et al. 2003). Similarly, we consulted with researchers with experience in queen conch husbandry (Pers. Comm. Davis, Pers. Comm. Delgado, Pers. Comm. Stoner) to assess the potential for relocation to cause physical or physiological injury to conch, and we believe that the effects of relocation on individual conch will be insignificant.

Table 3: Threats, Routes of Effect, and Potential Impacts that May Affect Queen Conch and Considerations for Effects Determinations. Activities denoted with an asterisk (*) may have impacts reduced to not-likely-to-adversely-affect levels based on application of the Queen Conch Survey, Construction Conditions, Relocation and Reporting Guidance, depending on scale, duration, and other project details.

Activity	Potential Route of Effects	Potential Impact to Species	Considerations
Federal Fisheries (only relevant in St. Croix)	• Potential entanglement and capture in fishing gear • Pots and traps pose a slight threat • Vast majority of queen conch harvest is done by hand	• Injury or mortality resulting from capture	• Safe handling and release procedures • Increase data collection and monitoring efforts, particularly location and size of individuals (i.e., shell length and lip thickness)
State Fisheries, Fishing, Fisheries related Research	• Potential entanglement and capture in fishing gear, particularly trawls • Vast majority of queen conch harvest is done by hand	• Injury or mortality resulting from capture	• Safe handling and release procedures • Increase data collection and monitoring efforts, particularly location and size of individuals (i.e., shell length and lip thickness) • Require posting of educational signage, and fisher outreach
Energy (Oil and Gas)*	• Exploration activities (e.g., exploratory drilling) • Direct fouling by oil/contaminants • Food source contamination • Habitat loss and/or degradation	• Sedimentation from exploration activities can be highly detrimental and potentially fatal • Decreased fertility, reproductive failure, or mortality through exposure to oil/contaminates • Health impacts from ingestion of contaminated food sources (algae, epiphytes, detritus) or lack of food	• Can minimization measures be put in place to reduce sedimentation and contamination? • Does the project have pollution/spill safeguards reporting requirements? • Does the action area occur within important spawning habitats (i.e., over 50 adults per hectare)?

Activity	Potential Route of Effects	Potential Impact to Species	Considerations
		• Habitat degradation and displacement from an action area	• Will visual surveys be conducted prior to activities? • Are there shut down or relocation procedures in place if a conch is observed?
Energy (Offshore Wind)*	• Seabed anchoring • Habitat loss, and/or degradation from sedimentation during construction • Construction activities	• Direct impact or sedimentation from anchoring of platforms and construction equipment • Habitat degradation Habitat loss from space occupied by installed structures	• What anchoring system is being used, and can minimization measures be implemented? • How much sedimentation will result from the proposed action? • Does the action area occur within important spawning habitats (i.e., over 50 adults per hectare)?
Aquaculture*	• Physical barrier • Habitat loss, degradation • Alter water quality and/or habitat • Construction activities	• Physical barrier on the benthos could block or impede movement in the area. Queen conch are not highly mobile and can easily get "trapped" in a low quality habitat • Water quality/habitat degradation could reduce foraging habitat • Increased nutrient load can lead to altered food sources • Increased fine sedimentation due to in-water activities can be highly detrimental to the species	• What is the type of equipment and duration of in-water construction? • Duration of the permit (i.e., how long will the project be in operation so we know how long any structures would be in the water)? • What is the configuration and design of the aquaculture equipment? • Does the action area occur within important spawning habitats (i.e., over 50 adults per hectare)? • What are the maintenance plans for the site (e.g., how often will water quality be inspected?)

Activity	Potential Route of Effects	Potential Impact to Species	Considerations
Dredging (e.g., Hopper, Clamshell, Cutter Head)	• Direct removal • Direct impact from equipment, including pipelines that pump dredged material from the source to the beach • Sedimentation on individuals of all life stages and habitats • Resuspension of sediment contaminants • Short and/or long-term habitat alteration/loss • Disruption of aggregation behavior • Smothering of food sources	• Injury or death due to interaction with equipment • Physical effects from sedimentation • Decreased fertility, reproductive failure, or mortality through exposure to contaminants • Health and reproductive impacts from starvation or ingestion of contaminated food sources (algae, epiphytes, detritus) • Habitat degradation and displacement from an action area	• Can the project use hydraulic dredging practices? • Type of equipment to be used and the duration of dredging? • What measures can be taken to ensure conch are not directly impacted by the dredge pipeline (e.g., floating the pipeline so it does not make contact with the bottom, or pipelines that are pinned to the bottom)? • What measures can be taken to ensure conch are not directly impacted by the dredge (e.g., require hydraulic dredging practices)? • What measures can be taken to reduce sedimentation? • Will sediment samples be taken to analyze contaminants? • Are there relocation procedures in place if a conch is observed? • Will observers be present (Hopper dredges only)? If so, consider data collection and tissue sampling to measure contaminants.
Coastal Construction: Marina, Dock, Ramp, Shoreline Stabilization,	• Direct impact from equipment • Sedimentation on individuals of all life stages, and on the habitat	• Injury or death due to interaction with equipment • Sedimentation from pile driving activities can directly or indirectly injure or kill queen conch	• Type of equipment to be used and the duration of in-water work? • What measures can be taken to reduce sedimentation? • Will soil samples be taken to analyze contaminants?

Activity	Potential Route of Effects	Potential Impact to Species	Considerations
Fishing Pier, & Slips*	• Resuspension of soil contaminants • Short and/or long-term habitat alteration	• Decreased fertility, reproductive failure, or mortality through exposure to contaminants • Health impacts from ingestion of contaminated food sources (algae, epiphytes, detritus) • Habitat degradation and displacement from an action area	• Are there relocation procedures in place if a conch is observed? • Will conch survey and construction guidance be followed?
Beach Nourishment (onshore placement or sand bypass; may overlap with Dredging, see above)*	• Direct removal • Direct impact from equipment • Burial • Sedimentation on individuals of all life stages and on the habitat • Resuspension of sediment contaminants • Short and/or long-term habitat alteration • Disruption of aggregation behavior • Smothering of food sources	• Injury or death due to interaction with equipment • Decreased fertility, reproductive failure, or mortality through exposure to contaminants • Health impacts from ingestion of contaminated food sources (algae, epiphytes, detritus) • Habitat degradation and displacement from an action area	• Type of equipment to be used and the duration of in-water work? • What measures can be taken to reduce sedimentation? • Will soil samples be taken to analyze contaminants? • Are there or relocation procedures in place if a conch is observed?
Habitat Restoration*	• Direct impact from equipment • Burial • Sedimentation on individuals and on the habitat • Resuspension of soil contaminants	• Injury or death due to interaction with equipment • Sedimentation from pile driving activities can be highly detrimental and potentially fatal • Decreased fertility, reproductive failure, and mortality through exposure to contaminants	• Type of habitat affected. Are there any beneficial effects? Creation or restoration reef habitat or other positive water quality/habitat enhancements • Type of equipment to be used and the duration of in-water work? • What measures can be taken to reduce sedimentation?

Activity	Potential Route of Effects	Potential Impact to Species	Considerations
	• Short and/or long-term habitat alteration	• Health impacts from ingestion of contaminated food sources (algae, epiphytes, detritus) • Habitat degradation and displacement from an action area	• Will soil samples be taken to analyze contaminants? • Are there relocation procedures in place if a conch is observed?
Outfalls, Water Releases, & Effluent Discharge*	• Long term habitat alteration • Contaminant releases	• Habitat degradation and displacement from the action area • Reduction in habitat and prey availability • Impacts of contaminants on reproduction and development • Health impacts from ingestion of contaminated food sources (e.g., algae, epiphytes, and detritus) • Behavioral and physical effects due to habitat degradation and displacement	• Project location and habitat type – is there similar habitat nearby without queen conch present where the outfall can be placed? • Project duration (temporary or long-term)? • Is the proposed project new? If not, can it improve on an existing outfall by installing an outfall baffle box?
Artificial Reef*	• Direct impact from equipment or reef material • Short and/or long-term habitat alteration • Blockage of migration or foraging corridors	• Injury or death due to interaction with equipment • Direct mortality through burial under dropped material • Mortality, decreased fertility, and reproductive failure through exposure to contaminants • Health impacts from ingestion of contaminated food sources (algae, epiphytes, detritus) • Behavioral and physical effects due to habitat degradation and displacement	• Type of artificial reef material • What measures can be taken to reduce sedimentation? • Will soil samples be taken to analyze contaminants? • Are there relocation procedures in place if a conch is observed? •

Activity	Potential Route of Effects	Potential Impact to Species	Considerations
Marine Debris Removal*	• Direct impact from equipment • Sedimentation on individuals and the habitat • Resuspension of soil contaminants • Short and/or long-term habitat alteration	• Injury or death due to interaction with equipment • Direct mortality through burial under dropped material • Sedimentation can be highly detrimental and potentially fatal • Impacts of contaminants on reproduction and development	• What type of equipment will be used to remove marine debris? • Will soil samples be taken to analyze contaminants? • Are relocation procedures in place if a conch is observed?

Section 7 and Recovery Integration

Conservation Activities and Recommendations

It is important to work with action agencies to promote proactive efforts to help conserve and recover the species. This will help the agency comply with its Section 7(a)(1) obligations, fill data gaps, improve the environmental baseline of species, and recover species so they no longer need the protections of the ESA. Regardless of consultation type (i.e., informal or formal consultation), conservation activities discussed early in the consultation process may be included as part of the proposed action. During formal consultation (i.e., a LAA determination), these may also be implemented through non-binding "Conservation Recommendations." Table 4 provides examples of several existing data gaps and research needs for queen conch in the Southeast.

Table 4: Existing data gaps and research needs for queen conch in the Southeast U.S.

Activity	Data Gap	Research Need
Federal and State Fisheries	Very little available data on population densities. Monitoring queen conch populations is difficult due to their extremely patchy distributions. There is a debate within the scientific community as to how to effectively quantify both cross-shelf and aggregation densities.	Evaluate different monitoring methodologies, and gather information on local population densities on both small and large scales.
Federal and State Fisheries	Very limited examples of effective alternatives to shell lip-thickness to estimate sexual maturity.	Evaluate other proxies to determine effective methods to estimate sexual maturity in individuals, including meat weight, and sexual organ development.
Federal and State Fisheries	Very limited information on age and growth in queen conch.	Evaluate age and growth patterns in queen conch and identify methods to determine age and growth rates.
All Federal Actions (e.g., nearshore construction, dredge and fill, energy	Limited data on important habitats and habitat features.	Identify breeding, aggregation sites, and nursery grounds; evaluate physical and

Activity	Data Gap	Research Need
development, fisheries, marina expansion, boat ramps, shoreline stabilization, and other large-scale actions).		environmental features driving site fidelity and/or repeated use of areas by queen conch
Dredging	Very limited data on sedimentation effects on queen conch health, survival, and fecundity.	Evaluate the effects and physiological responses of sedimentation exposure on individuals of all life stages and sizes.
Dredging	Limited data on the effects of contaminants (i.e., pollutants) to queen conch survival, fecundity, and overall health.	Evaluate the effects and physiological responses of contamination on individuals of all life stages and sizes.
Relocation of queen conch	Limited data on responses to relocation.	Evaluate best practices for the relocation of individuals and monitor the effects to the overall health, survival, and fecundity of individuals.
Relocation of queen conch	Limited data on appropriate areas for relocation.	Support scientific surveys to document queen conch habitats throughout their range, particularly in areas where permanent relocations are likely to be attempted. This will increase flexibilities in relocation procedures and reduce transfer times for conch.
Relocation of queen conch	Limited data on temporary relocation	Support experiments with relocating queen conch to neighboring sites near to construction projects to determine whether queen conch will adapt to the relocation or attempt to return

Activity	Data Gap	Research Need
		to the location they were relocated from.
Construction activities (e.g., nearshore construction, dredge and fill, energy development, fisheries, marina expansion, boat ramps, shoreline stabilization, and other large-scale actions).	Limited data on effects of noise to queen conch.	Evaluate the effects and physiological responses of noise on individuals of all life stages and sizes.
Construction activities	Effects of turbidity	Support studies on whether queen conch affected by turbidity from course sediment to understand whether queen conch need to be relocated off of most minor project sites or within a buffer from turbidity. Support projects that look at whether a queen conch will move towards turbidity on a project footprint or away.
Surveys	What is an appropriate survey buffer	Is the maximum queen conch movement per day appropriate for use in surveying? Do queen conch move toward the project footprint once removed? Are there different times of year when buffers could be smaller?
Surveys	What is an appropriate survey duration	How many surveys are necessary to determine that queen conch will not be in an area? What is the timeframe

Activity	Data Gap	Research Need
		under which a queen conch survey result will change?
Surveys	Time of year	Are there differences in survey protocols that could be implemented based on time of year?
Range and habitat usage	Understanding where we should target surveys for queen conch	With each permitted project, we are getting a better understanding of where queen conch are located, the habitats that they are found in, and where they are absent. Analysis of these surveys will help to inform where queen conch live, and where they don't.

Cooperative engagement between action agencies and NMFS provides an opportunity to establish or strengthen partnerships and provide action agencies the opportunity to proactively implement measures beneficial to ESA species. Action agencies should give thought to possible conservation activities based on the project type, location, and the applicant performing the activity and consider whether conservation recommendations can be incorporated into a project.

No recovery plan or outline has been developed yet for queen conch. Once recovery actions are identified, they will be incorporated here.

Literature Cited

Acosta, C. A. 2001. Assessment of the functional effects of a harvest refuge on spiny lobster and queen conch populations at Glover's Reef, Belize. Pages 212-221 *in* Proceedings of the 52nd Gulf and Caribbean Fisheries Institute, volume 52. Gulf and Caribbean Fisheries Institute, North Fort Pierce, FL.

Acosta, C. A. 2006. Impending trade suspensions of Caribbean queen conch under CITES: A case study on fishery impacts and potential for stock recovery. Fisheries 31(12):601-606.

Appeldoorn, R. S. 1985. Growth, mortality and dispersion of juvenile, laboratory-reared conchs, *Strombus gigas* and *S. costatus*, released at an offshore site. Bulletin of Marine Science 37(3):785-793.

Appeldoorn, R. S. 1988a. Age determination, growth, mortality and age of first reproduction in adult queen conch, *Strombus gigas* L., off Puerto Rico. Fisheries Research 6(4):363-378.

Appeldoorn, R. S. 1988b. Fishing pressure and reproductive potential in strombid conchs: Is there a critical stock density for reproduction? Memoria de la Sociedad de Ciencas Naturales La Salle 48(Supplement 3):275-288.

Appeldoorn, R. S. 1988c. Ontogenetic changes in natural mortality rate of queen conch, Strombus gigas (Mollusca: Mesogastropoda). Bulletin of Marine Science 42(2):159-165.

Appeldoorn, R. S. 1993. Reproduction, spawning potential ratio and larval abundance of queen conch off La Parguera, Puerto Rico. University of Puerto Rico, Department of Marine Sciences, Manuscript Report to Caribbean Fishery Management Council. San Juan, Puerto Rico, Mayaguez, Puerto Rico.

Appeldoorn, R. S. 1995. Potential depensatory mechanisms operating on reproductive output in gonochoristic molluscs, with particular reference to strombid gastropods. Pages 13-18 *in* ICES Marine Science Symposia, volume 199. International Council for the Exploration of the Sea, Copenhagen, Denmark.

Appeldoorn, R. S. 2020. Size at Maturation, Spawning Variability and Fecundity in the Queen Conch, Aliger gigas. Gulf and Caribbean Research 31(1):GCFI 10-GCFI 19.

Berg Jr., C. J., and D. A. Olsen. 1989. 18. Conservation and management of queen conch (*Strombus gigas*) fisheries in the Caribbean. Pages 421-442 *in* J. F. Caddy, editor. Marine invertebrate fisheries: their assessment and management. Wiley and Sons New York, NY.

Berg Jr., C. J., J. Ward, B. E. Luckhurst, K. Nisbet, and F. Couper. 1992. Observations of breeding aggregations of the queen conch, *Strombus gigas*, in Bermuda. Pages 161-171 *in* Proceedings of the 42nd Gulf and Caribbean Fisheries Institute, volume 42. Gulf and Caribbean Fisheries Institute, North Fort Pierce, FL.

Boman, E. M., and coauthors. 2019. Diet and growth of juvenile queen conch *Lobatus gigas* (Gastropoda: Strombidae) in native, mixed and invasive seagrass habitats. Marine Ecology Progress Series 621:143-154.

Chau, Y. K., R. J. Maguire, M. Brown, F. Yang, and S. P. Batchelor. 1997. Occurrence of organotin compounds in the Canadian aquatic environment five years after the regulation of antifouling uses of tributyltin. Water Quality Research Journal 32(3):453-522.

Coulston, M. L., R. W. Berey, A. C. Dempsey, and P. Odum. 1987. Assessment of the queen conch (*Strombus gigas*) population and predation studies of hatchery reared juveniles in Salt River Canyon, St. Croix, U.S. Virgin Islands. Pages 294-306 *in* Proceedings of the 38th Gulf and Caribbean Fisheries Institute, volume 38. Gulf and Caribbean Fisheries Institute, North Fort Pierce, FL.

Creswell, R. L. 1994. An historical overview of queen conch mariculture. Pages 223-230 *in* R. S. Appeldoom, and B. Rodriguez Q., editors. Queen conch biology, fisheries and mariculture. Fundación Científica Los Roques, Caracas, Venezuela.

D'Asaro, C. N. 1965. Organogenesis, development, and metamorphosis in the queen conch, *Strombus gigas*, with notes on breeding habits. Bulletin of Marine Science 15(2):359-416.

Davis, M. 2005. Speces profile: Queen conch, *Strombus gigas*, Southern Regional Aquaculture Center Publication No. 7203.

Davis, M., and C. Hesse. 1983. Third world level conch mariculture in the Turks and Caicos Islands. Pages 73-82 *in* Proceedings of the 35th Gulf and Caribbean Fisheries Institute, volume 35. Gulf and Caribbean Fisheries Institute, North Fort Pierce, FL.

Davis, M., B. A. Mitchell, and J. L. Brown. 1984. Breeding behavior of the queen conch *Strombus gigas* Linné held in a natural enclosed habitat. Journal of Shellfish Research 4(1):17-21.

Delgado, G. A., C. T. Bartels, R. A. Glazer, N. J. Brown-Peterson, and K. J. McCarthy. 2004. Translocation as a strategy to rehabilitate the queen conch (*Strombus gigas*) population in the Florida Keys. Fishery Bulletin 102(2):278-288.

Delgado, G. A., and R. A. Glazer. 2007. Interactions between translocated and native queen conch *Strombus gigas*: Evaluating a restoration strategy. Endangered Species Research 3(3):259-266.

Delgado, G. A., and R. A. Glazer. 2020. Demographics influence reproductive output in queen conch (*Lobatus gigas*): Implications for fishery management. Bulletin of Marine Science 96(4):707-721.

Doerr, J. C., and R. L. Hill. 2013. Home range, movement rates, and habitat use of queen conch, Strombus gigas, in St. John, US Virgin Islands. Caribbean Journal of Science 47(2-3):251-259.

Doerr, J. C., and R. L. Hill. 2018. Spatial distribution, density, and habitat associations of queen conch *Strombus gigas* in St. Croix, US Virgin Islands. Marine Ecology Progress Series 594:119-133.

Erisman, B., and coauthors. 2017. Fish spawning aggregations: Where well-placed management actions can yield big benefits for fisheries and conservation. Fish and Fisheries 18(1):128-144.

Farmer, N. A., and J. C. Doerr. 2022. Limiting factors for queen conch (Lobatus gigas) reproduction: A simulation-based evaluation. Plos One 17(3):e0251219.

García-Sais, J. R., J. Sabater-Clavell, R. Esteves, and M. Carlo. 2012. Fishery-independent survey of commercially exploited fish and shellfish populations from mesophotic reefs within the Puerto Rican Exclusive Economic Zone: Final report. Caribbean Fisheries Management Council, San Juan, Puerto Rico.

Gascoigne, J., and R. N. Lipcius. 2004. Conserving populations at low abundance: Delayed functional maturity and Allee effects in reproductive behaviour of the queen conch *Strombus gigas*. Marine Ecology Progress Series 284:185-194.

Glazer, R. A., and C. J. Berg Jr. 1994. Queen conch research in Florida: An overview. Pages 79-95 *in* R. S. Appeldoom, and B. Rodriguez Q., editors. Queen conch biology, fisheries and mariculture. Fundación Científica Los Roques, Caracas, Venezuela.

Glazer, R. A., G. A. Delgado, and J. A. Kidney. 2003. Estimating queen conch (*Strombus gigas*) home ranges using acoustic telemetry: Implications for the design of marine fishery reserves. Gulf and Caribbean Research 14(2):79-89.

Glazer, R. A., and J. A. Kidney. 2004. Habitat associations of adult queen conch (*Strombus gigas* L.) in an unfished Florida Keys back reef: Applications to essential fish habitat. Bulletin of Marine Science 75(2):205-224.

Glazer, R. A., and I. Quintero. 1998. Observations on the sensitivity of queen conch to water quality: Implications for coastal development. Pages 78-93 *in* Proceedings of the 50th Gulf and Caribbean Fisheries Institute, volume 50. Gulf and Caribbean Fisheries Institute, North Fort Pierce, FL.

Hesse, K. O. 1979. Movement and migration of the queen conch, *Strombus gigas*, in the Turks and Caicos Islands. Bulletin of Marine Science 29(3):303-311.

Horn, C., and coauthors. 2022. Endangered species act status review report: Queen conch (Aliger gigas).

Jones, R. L., and A. W. Stoner. 1997. The integration of GIS and remote sensing in an ecological study of queen conch, *Strombus gigas*, nursery habitat. Pages 523-530 *in* Proceedings of the 49th Gulf and Caribbean Fisheries Institute, volume 49. Gulf and Caribbean Fisheries Institute, North Fort Pierce, FL.

Marshak, A. R., R. S. Appeldoorn, and N. Jiménez. 2006. Utilization of GIS mapping in the measurement of the spatial distribution of queen conch (*Strombus gigas*) in Puerto Rico. Pages 31-47 *in* Proceedings of the 57th Gulf and Caribbean Fisheries Institute, volume 57. Gulf and Caribbean Fisheries Institute, North Fort Pirece, FL.

McCarthy, K. 2007. A review of queen conch (*Strombus gigas*) life-history. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, SEDAR 14-DW-4, Miami, FL.

Mianmanus, R. T. 1988. Induction of settlement and metamorphosis in larvae of *Aplysia brasiliana* and *Strombus gigas* (Mollusca: Gastropoda). Ph.D. Dissertation. University of Miami, Miami, FL.

Paris, C. B., D. Aldana-Aranda, M. Pérez-Pérez, and J. Kool. 2008. Connectivity of queen conch, *Strombus gigas*, populations from Mexico. Pages 439-443 *in* B. Riegl, and R. E. Dodge, editors. Proceedings of the 11th International Coral Reef Symposium, volume 11. Nova Southeastern University, National Coral Reef Institute, Davie, FL.

Posada, J. M., and R. S. Appeldoorn. 1994. Preliminary observations on the distribution of *Strombus* larvae in the eastern Caribbean. Pages 191-199 *in* R. S. Appeldoom, and B. Rodriguez Q., editors. Queen conch biology, fisheries and mariculture. Fundación Científica Los Roques, Caracas, Venezuela.

Posada, J. M., G. García-Moliner, and I. N. Oliveras (editors). 1997. Proceedings International Queen Conch Conference *Strombus gigas*. Caribbean Fishery Management Council, NOAA award No. NA77FC0004, San Juan, Puerto Rico.

Randall, J. E. 1964. Contributions to the biology of the queen conch, *Strombus gigas*. Bulletin of Marine Science 14(2):246-295.

Ray, M., and A. W. Stoner. 1995. Growth, survivorship, and habitat choice in a newly settled seagrass gastropod, *Strombus gigas*. Marine Ecology Progress Series 123:83-94.

Robertson, R. 1959. Observations on the spawn and veligers of conchs (*Strombus*) in the Bahamas. Journal of Molluscan Studies 33(4):164-171.

Rossetto, M., F. Micheli, A. Saenz-Arroyo, J. A. E. Montes, and G. A. De Leo. 2015. No-take marine reserves can enhance population persistence and support the fishery of abalone. Canadian Journal of Fisheries and Aquatic Sciences 72(10):1503-1517.

Serviere-Zaragoza, E., A. Mazariegos-Villareal, and D. Aldana-Aranda. 2009. Preliminary observation of natural feed of queen conch *Strombus gigas*. Pages 514-517 *in* Proceedings of the 61st Gulf and Caribbean Fisheries Institute, volume 61. Gulf and Caribbean Fisheries Institute, North Fort Pierce, FL.

Spade, D. J., and coauthors. 2010. Queen conch (*Strombus gigas*) testis regresses during the reproductive season at nearshore sites in the Florida Keys. Plos One 5(9):e12737.

Stephens, P. A., and W. J. Sutherland. 1999. Consequences of the Allee effect for behaviour, ecology and conservation. Trends in ecology & evolution 14(10):401-405.

Stoner, A., M. Davis, and C. Booker. 2011. Surveys of queen conch populations and reproductive biology at Lee Stocking Island and the Exuma Cays Land and Sea Park, The Bahamas, Community Conch, Bahamas.

Stoner, A. W. 1989a. Density-dependent growth and grazing effects of juvenile queen conch *Strombus gigas* L. in a tropical seagrass meadow. Journal of Experimental Marine Biology and Ecology 130(2):119-133.

Stoner, A. W. 1989b. Winter mass migration of juvenile queen conch *Strombus gigas* and their influence on the benthic environment. Marine Ecology Progress Series 56(1):99-104.

Stoner, A. W. 2003. What constitutes essential nursery habitat for a marine species? A case study of habitat form and function for queen conch. Marine Ecology Progress Series 257:275-289.

Stoner, A. W., and R. S. Appeldoorn. 2022. Synthesis of Research on the Reproductive biology of queen conch (Aliger gigas): toward the goals of sustainable fisheries and species conservation. Reviews in Fisheries Science & Aquaculture 30(3):346-390.

Stoner, A. W., and M. Davis. 1997. Abundance and distribution of queen conch veligers (*Strombus gigas* Linne) in the central Bahamas. I. Horizontal patterns in relation to reproductive and nursery grounds. Journal of Shellfish Research 16(1):7-18.

Stoner, A. W., and M. H. Davis. 2010. Queen conch stock assessment historical fishing grounds Andros Island, Bahamas. Community Conch, Report by Community Conch to the Nature Conservancy, Nassau, Bahamas, Nassau, Bahamas.

Stoner, A. W., M. H. Davis, and C. J. Booker. 2012a. Evidence for a significant decline in queen conch in the Bahamas, including the population in a marine protected area. Pages 349-

361 *in* Proceedings of the 64th Gulf and Caribbean Fisheries Institute, volume 64. Gulf and Caribbean Fisheries Institute, North Fort Pierce, FL.

Stoner, A. W., M. H. Davis, and C. J. Booker. 2012b. Negative consequences of Allee effect are compounded by fishing pressure: Comparison of queen conch reproduction in fishing grounds and a marine protected area. Bulletin of Marine Science 88(1):89-104.

Stoner, A. W., M. H. Davis, and A. S. Kough. 2019. Relationships between fishing pressure and stock structure in queen conch (*Lobatus gigas*) populations: Synthesis of long-term surveys and evidence for overfishing in The Bahamas. Reviews in Fisheries Science & Aquaculture 27(1):51-71.

Stoner, A. W., and R. A. Glazer. 1998. Variation in natural mortality: Implications for queen conch stock enhancement. Bulletin of Marine Science 62(2):427-442.

Stoner, A. W., R. A. Glazer, and P. J. Barile. 1996. Larval supply to queen conch nurseries: Relationships with recruitment process and population size in Florida and the Bahamas. Journal of Shellfish Research 15(2):407-420.

Stoner, A. W., and J. Lally. 1994. High-density aggregation in queen conch *Strombus gigas*: Formation, patterns, and ecological significance. Marine Ecology Progress Series 106:73-84.

Stoner, A. W., and M. Ray-Culp. 2000. Evidence for Allee effects in an over-harvested marine gastropod: Density-dependent mating and egg production. Marine Ecology Progress Series 202:297-302.

Stoner, A. W., and M. Ray. 1993. Aggregation dynamics in juvenile queen conch (*Strombus gigas*): Population structure, mortality, growth, and migration. Marine Biology 116(4):571-582.

Stoner, A. W., M. Ray, and J. M. Waite. 1995. Effects of a large herbivorous gastropod on macrofauna communities in tropical seagrass meadows. Marine Ecology Progress Series 121:125-137.

Stoner, A. W., and V. J. Sandt. 1992. Population structure, seasonal movements and feeding of queen conch, *Strombus gigas*, in deep-water habitats of the Bahamas. Bulletin of Marine Science 51(3):287-300.

Stoner, A. W., and J. M. Waite. 1991. Trophic biology of *Strombus gigas* in nursery habitats: Diets and food sources in seagrass meadows. Journal of Molluscan Studies 57(4):451-460.

Theile, S. 2001. Queen conch fisheries and their management in the Caribbean. TRAFFIC Europe, Technical report to the CITES Secretariat in completion of contract A-2000/01, Brussels, Belgium.

Titley-O'Neal, C. P., B. A. MacDonald, É. Pelletier, R. Saint-Louis, and O. S. Phillip. 2011. The relationship between imposex and tributyltin (TBT) concentration in *Strombus gigas* from the British Virgin Islands. Bulletin of Marine Science 87(3):421-435.

Torres Rosado, Z. A. 1987. Distribution of two mesogastropods, the queen conch, *Strombus gigas* Linnaeus, and the milk conch, *Strombus costatus* Gmelin in La Parguera, Lajas, Puerto Rico. Master's Thesis. University of Puerto Rico, Mayagüez Campus, Mayagüez, Puerto Rico.

Vaz, A. C., and coauthors. 2022. Exploitation drives changes in the population connectivity of queen conch (Aliger gigas). Frontiers in Marine Science 9:841027.

Weil, E. M., and R. G. Laughlin. 1984. Biology, population dynamics, and reproduction of the queen conch *Strombus gigas* Linné in the Archipiélago de Los Roques National Park. Journal of Shellfish Research 4(1):45-62.