Agenda Item G.1.a
Supplemental REVISED NMFS Report 1 (**electronic only**)
April 2023

■ 3. Add a new § 367.40 to read as follows:

§ 3
Registration Plan and Agreement for Registration Years Beginning in 2024 and Each Subsequent Registration Year Thereafter.

TABLE 1 TO § 367.40—FEES UNDER THE UNIFIED CARRIER REGISTRATION PLAN AND AGREEMENT FOR REGISTRATION YEARS BEGINNING IN 2024 AND EACH SUBSEQUENT REGISTRATION YEAR THEREAFTER

Bracket	Number of commercial motor vehicles owned or operated by exempt or non-exempt motor carrier, motor private carrier, or freight forwarder	Fee per entity for exempt or non-exempt motor carrier, motor private carrier, or freight forwarder	Fee per entity for broker or leasing company
B1	0–2	$37	$37
B2	3–5	111	
B3	6–20	221	
B4	21–100	769	
B5	101–1,000	3,670	
B6	1,001 and above	35,836	

Issued under authority delegated in 49 CFR 1.87.

Robin Hutcheson,
Administrator.

[FR Doc. 2023–05292 Filed 3–15–23; 8:45 am]

BILLING CODE 4910–EX–P

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

50 CFR Part 223

[Docket No. 230309–0070; RTID 0648–XR120]

Proposed Rule To List the Sunflower Sea Star as Threatened Under the Endangered Species Act

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Proposed rule; request for comments.

SUMMARY: We, NMFS, have completed a comprehensive status review for the sunflower sea star, *Pycnopodia helianthoides,* in response to a petition to list this species as threatened or endangered under the Endangered Species Act (ESA). Based on the best scientific and commercial information available, including the draft status review report, and after taking into account efforts being made to protect the species, we have determined that the sunflower sea star is likely to become an endangered species within the foreseeable future throughout its range. Therefore, we propose to list the sunflower sea star as a threatened species under the ESA. Should the proposed listing be finalized, any protective regulations under section 4(d) of the ESA would be proposed in a separate **Federal Register** notice. We do not propose to designate critical habitat at this time because it is not currently determinable. We are soliciting information to inform our final listing determination, as well as the development of potential protective regulations and critical habitat designation.

DATES: Comments on the proposed rule to list the sunflower sea star must be received by May 15, 2023. Public hearing requests must be made by May 1, 2023.

ADDRESSES: You may submit comments on this document, identified by NOAA–NMFS–2021–0130, by either of the following methods:

- *Electronic Submissions:* Submit all electronic public comments via the Federal e-Rulemaking Portal. Go to *www.regulations.gov* and enter NOAA–NMFS–2021–0130 in the Search box. Click on the “Comment” icon, complete the required fields, and enter or attach your comments.
- *Mail:* Submit written comments to Dayv Lowry, NMFS West Coast Region Lacey Field Office, 1009 College St. SE, Lacey, WA 98503, USA.
- *Fax:* 360–753–9517; Attn: Dayv Lowry.

Instructions: Comments sent by any other method, to any other address or individual, or received after the end of the comment period, may not be considered by NMFS. All comments received are a part of the public record and will generally be posted for public viewing on *www.regulations.gov* without change. All personally identifying information (*e.g.,* name, address), confidential business information, or otherwise sensitive information submitted voluntarily by the sender will be publicly accessible. NMFS will accept anonymous comments (enter “N/A” in the required fields if you wish to remain anonymous).

The petition, draft status review report (Lowry *et al.* 2022), **Federal Register** notices, and the list of references can be accessed electronically online at: *https://www.fisheries.noaa.gov/species/sunflower-sea-star.* The peer review plan and charge to peer reviewers are available at *https://www.noaa.gov/organization/information-technology/peer-review-plans.*

FOR FURTHER INFORMATION CONTACT: Dayv Lowry, NMFS, West Coast Region Lacey Field Office, (253) 317–1764.

SUPPLEMENTARY INFORMATION:

Background

On August 18, 2021, we received a petition from the Center for Biological Diversity to list the sunflower sea star (*Pycnopodia helianthoides*) as a threatened or endangered species under the ESA. On December 27, 2021, we published a positive 90-day finding (86 FR 73230, December 27, 2021) announcing that the petition presented substantial scientific or commercial information indicating that the petitioned action may be warranted. We also announced the initiation of a status review of the species, as required by section 4(b)(3)(A) of the ESA, and requested information to inform the agency's decision on whether this species warrants listing as threatened or endangered.

Listing Species Under the Endangered Species Act

To make a determination whether a species is threatened or endangered under the ESA, we first consider whether it constitutes a "species" as defined under section 3 of the ESA, and then whether the status of the species qualifies it for listing as either threatened or endangered. Section 3 of the ESA defines species to include subspecies and, for any vertebrate species, any distinct population segment (DPS) which interbreeds when mature (16 U.S.C. 1532(16)). Because the sunflower sea star is an invertebrate, the ESA does not permit us to consider listing DPSs.

Section 3 of the ESA defines an endangered species as "any species which is in danger of extinction throughout all or a significant portion of its range" and a threatened species as one "which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." Thus, in the context of the ESA, we interpret an "endangered species" to be one that is presently in danger of extinction, while a "threatened species" is not currently in danger of extinction, but is likely to become so in the foreseeable future (that is, at a later time). The primary statutory difference between a threatened and endangered species is the timing of when a species is in danger of extinction, either presently (endangered) or not presently but within the foreseeable future (threatened). Being in danger of extinction "presently" does not mean that the possible extinction event is necessarily now.

When we consider whether a species qualifies as threatened under the ESA, we must consider the meaning of the term "foreseeable future." It is appropriate to interpret "foreseeable future" as the horizon over which predictions about the conservation status of the species can be reasonably relied upon. What constitutes the foreseeable future for a particular species depends on factors such as life history parameters, habitat characteristics, availability of data, the nature of specific threats, the ability to predict impacts from threats, and the reliability of forecasted effects of these threats on the status of the species under consideration. Because a species may be susceptible to a variety of threats for which different data are available, or which operate across different time scales, the foreseeable future may not be reducible to a discrete number of years.

Section 4(a)(1) of the ESA requires us to determine whether a species is endangered or threatened throughout all or a significant portion of its range as a result of any one, or a combination of, the following factors: (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence (16 U.S.C. 1533(a)(1)). We are also required to make listing determinations based solely on the best scientific and commercial data available, after conducting a review of the species' status and after taking into account efforts, if any, being made by any state or foreign nation (or subdivision thereof) to protect the species (16 U.S.C. 1533(b)(1)(A)).

Status Review

After publishing the 90-day finding indicating that listing may be warranted for the sunflower sea star, the NMFS West Coast Regional Office convened a Status Review Team (SRT) composed of marine biologists, ecologists, statisticians, and natural resource managers from the NMFS Alaska and West Coast Regional Offices; NMFS Alaska, Northwest, and Southwest Fisheries Science Centers; United States Geological Survey; and Monterey Bay National Marine Sanctuary. This team also received input from state, provincial, tribal, non-profit, and academic experts. The SRT compiled and synthesized all available information into a comprehensive draft status review report (Lowry *et al.* 2022, see **ADDRESSES** section). The draft status review report summarizes the best available scientific and commercial information on the biology, ecology, life history, and status of the sunflower sea star, as well as stressors and threats facing the species. The SRT also considered information submitted by the public in response to our 90-day petition finding (86 FR 73230; December 27, 2021).

The draft status review report is undergoing independent peer review as required by the Office of Management and Budget (OMB) Final Information Quality Bulletin for Peer Review (M–05–03; December 16, 2004) concurrent with public review of this proposed rule. Independent specialists were selected from the academic and scientific community, with expertise in sea star biology, conservation policy, and applied natural resource management. The peer reviewers were asked to evaluate the adequacy, appropriateness, and application of data used in the status review, including the extinction risk analysis. The peer review plan and charge statement are available on NOAA's website (see **ADDRESSES** section). All peer reviewer comments will be made publicly available and addressed prior to dissemination of the final status review report and publication of the final listing decision.

Below is a summary of the biology and ecology of the sunflower sea star, accompanied by an evaluation of threats facing the species, and resulting extinction risk. This information is presented in greater detail in the draft status review report (Lowry *et al.* 2022), which is available on our website (see **ADDRESSES** section). In addition to evaluating the status review, we independently applied the statutory provisions of the ESA, including evaluation of protective efforts set forth in section 4(b)(1)(A) and our regulations regarding listing determinations at 50 CFR part 424, to making our determination that the sunflower sea star meets the definition of a threatened species under the ESA.

Description, Life History, and Ecology of the Petitioned Species

Species Taxonomy and Description

The sunflower sea star was originally described as *Asterias helianthoides* by Brandt (1835), a species of sea star unique in having 16 to 20 rays (arms) and found in coastal marine waters near Sitka, Alaska. Stimpson (1861) later designated it as the type species of the new genus *Pycnopodia* and as the only known species of the family Pycnopodiidae. Fisher (1922) described the Pacific starfish *Lysastrosoma anthosticta* as a new species, stating it was closely related to *Pycnopodia,* and subsequent authors have included only these two species in the subfamily Pycnopodiinae. *Pycnopodia helianthoides* has no known synonyms, and the validity of the species has not been questioned in the taxonomic literature. Therefore, based on the best available scientific and commercial information, we find that the scientific consensus is that *P. helianthoides* is a taxonomically distinct species and, therefore, meets the definition of "species" pursuant to section 3 of the ESA. Below, we evaluate whether this species warrants listing as endangered or threatened under the ESA throughout all or a significant portion of its range.

The sunflower sea star is among the largest sea stars in the world, reaching over 1 meter (m) in total diameter from ray tip to ray tip across the central disk.

The sunflower sea star and closely related Pacific starfish are distinguished from other co-occurring sea stars by their greatly reduced abactinal (dorsal) skeleton with no actinal plates, and by their prominently crossed pedicellariae (Fisher 1928). Very young sunflower sea stars generally have fewer than a dozen arms, and additional arms are added by budding in symmetrical pairs as the individual grows. Other sea stars in the northern Pacific Ocean with many arms include several sun stars of the genera *Solaster, Crossaster,* and *Rathbunaster;* however, these species generally have 8 to 17 arms, as opposed to the 16 to 20 arms commonly found in the sunflower sea star, and all of the sun stars are considerably smaller and less massive (Fisher 1906).

Range, Distribution, and Habitat Use

The documented geographic range of the sunflower sea star spans the Northeastern Pacific Ocean from the Aleutian Islands to Baja California (Sakashita 2020). This range includes 33 degrees of latitude (3,663 km) across western coasts of the continental United States, Canada, and northern Mexico. The farthest reaches of sunflower sea star observations include: northernmost—Bettles Bay, Anchorage, Alaska (Gravem *et al.,* 2021); westernmost—central and eastern Aleutian Islands (Kuluk Bay, Adak Island east to Unalaska Island, Samalga Pass, and Nikolski) (Feder 1980; O'Clair and O'Clair 1998; Jewett *et al.* 2015; Gravem *et al.* 2021); and southernmost—Bahia Asunción, Baja California Sur, Mexico (Gravem *et al.* 2021). The sunflower sea star is generally most common from the Alaska Peninsula to Monterey, California.

The sunflower sea star has no clear associations with specific habitat types or features and is considered a habitat generalist (Gravem *et al.* 2021 and citations therein). The large geographic and depth range of the sunflower sea star indicates this species is well adapted for a wide variety of environmental conditions and habitat types. The species is found along both outer coasts and inside waters, which consist of glacial fjords, sounds, embayments, and tidewater glaciers. Preferring temperate waters, they inhabit kelp forests and rocky intertidal shoals (Hodin *et al.* 2021), but are regularly found in eelgrass meadows as well (Dean and Jewett 2001; Gravem *et al.* 2021). Sunflower sea stars occupy a wide range of benthic substrates including mud, sand, shell, gravel, and rocky bottoms while roaming in search of prey (Konar *et al.* 2019; Lambert *et al.* 2000). They occur in the low intertidal and subtidal zones to a depth of 435 m but are most common at depths less than 25 m and rare in waters deeper than 120 m (Fisher 1928; Lambert 2000; Hemery *et al.* 2016; Gravem *et al.* 2021). This characterization of their prevalence across depth ranges, however, may be biased by: (1) differential sampling methods and effort, with SCUBA-based observations dominating records; and (2) the propensity to record all sea stars as "sea star unidentified" when they occur as incidental bycatch in various survey and fishery records.

Reproduction, Growth, and Longevity

Most sea star species, including the sunflower sea star, have separate sexes that are externally indistinguishable from one another, and each ray of an adult contains a pair of gonads (Chia and Walker 1991). In the sunflower sea star, gonads are elongated, branched sacs that fill the length of each ray when ripe (Chia and Walker 1991). Gametes are broadcast through gonopores on each ray into the surrounding seawater and fertilization occurs externally. Fertilized larvae develop through pelagic planktotrophic stages, capturing food with ciliary bands (Strathmann 1971; 1978; Byrne 2013).

A number of environmental factors, such as food availability, seawater temperature, photoperiod, salinity, and the lunar cycle, may control seasonality of sea star reproductive cycles (Chia and Walker 1991; Pearse *et al.* 1986). Although the reproductive season of several Northeast Pacific sea stars have been estimated by following oocyte-diameter frequency distributions (*e.g.,* Farmanfarmaian *et al.* 1958; Mauzey 1966; Pearse and Eernisse 1982), to the best of our knowledge no one has conducted such studies in free-ranging sunflower sea stars. However, a number of researchers have estimated reproductive seasonality of the species based on observations of either field or laboratory spawning. Mortenson (1921) reported that sunflower sea stars breed from May through June at Nanaimo, British Columbia, while Greer (1962) collected adult broodstock from the intertidal zone at San Juan Island, Washington, and reported spawning in March and April. Feder (1980) obtained fertilizable eggs from December through June in California, and Strathmann (1987) stated that spawning occurs from late March through July, peaking from May through June with some large males spawning into December and January. More recently, Hodin *et al.* (2021) suggested that the reproductive season for females begins in November through January and ends in April and May in Washington. It is possible that a slightly altered photoperiod and constant availability of food for these lab-held specimens, however, may have caused individuals to exhibit altered reproductive seasonality, explaining the apparent discrepancy. Hodin *et al.* (2021) also note that the reproductive season for females occurs later in Alaska.

Typically, sea stars with planktotrophic larval (*i.e.,* reliant on planktonic prey) development from the Northwest Pacific Ocean spawn in late winter or early spring, which provides the best growing conditions for their offspring by synchronizing their occurrence with the spring phytoplankton bloom (Menge 1975; Strathmann 1987). The spawning seasons of several other sea stars with planktotrophic larval development in the Pacific Northwest and on the U.S. West Coast occurs between March and August (Mortensen 1921; Farmanfarmaian *et al.* 1958; Mauzey 1966; Feder 1980; Fraser *et al.* 1981; Pearse and Eernisse 1982; Strathmann 1987; Pearse *et al.* 1988; Sanford and Menge 2007). In addition, many temperate sea stars, such as the ochre star (*Pisaster ochraceus*), have seasonal, cyclical feeding patterns, such that feeding activity is reduced during the late fall and winter (Feder 1980; Mauzey 1966; Sanford and Menge 2007). This may also be the case for the sunflower sea star but direct documentation of this phenomenon is lacking. Planktotrophic larvae of the sunflower sea star developing during winter (November to February) in the Northeast Pacific Ocean would be at a distinct disadvantage due to the scarcity of planktonic algae at that time.

We were unable to find direct estimates of fecundity for female sunflower sea stars anywhere in the literature or in unpublished records. However, Strathmann (1987) states that ripe ovaries of specimens about 60 cm across may weigh 400 to 800 grams (g). Comparing this estimate with fecundity estimates for the ochre star, a Northeast Pacific sea star that has similar egg size and reproductive strategy, may give some insight to potential fecundity of the sunflower sea star. Menge (1974) estimated that a typically sized female ochre star weighing 400 g wet weight would produce ~40 million eggs, representing an average of 9 to 10 percent of wet weight being put into reproductive effort. As the wet weight of ochre stars ranges up to 650 g (Menge 1975), a female of this size could spawn considerably many more than 40 million eggs in a season. However, Fraser *et al.* (1981) believed that Menge's (1974) estimate of 40 million eggs for a 400 g adult was somewhat high and calculated that a specimen weighing 315 g would produce ~8 million total eggs. Given that sunflower sea stars can grow to a massive five kilograms (kg) (Fisher 1928; Lambert 2000), and assuming sunflower sea stars and ochre stars invest similar resources into reproductive efforts, it is conceivable that a 4.5 kg female sunflower sea star could produce upwards of 114 million eggs in a gonadal cycle using the conservative estimate of Fraser *et al.* (1981). This level of potential egg production is comparable to estimates for the crown-of-thorns sea star, *Acanthaster* spp. (Babcock *et al.* 2016), potentially making the sunflower sea star one of the most fecund sea stars in the world. This high potential fecundity is debatable, however, given recent observations of gonad size in captive sunflower sea stars. Hodin *et al.* (2021) noted that even when reproductively mature, gonads tend to be no more than a few centimeters in length, which is small relative to other sea stars of the Northwest Pacific Ocean.

Regarding size at sexual maturity, near Bremerton, Washington, Kjerskog-Agersborg (1918) noted that maturity is not entirely dependent on size. While females are on the average larger than males, immature individuals of both sexes were found across a broad range of sizes—including some of the largest individuals sampled. In a status assessment conducted for the International Union for Conservation of Nature (IUCN), Gravem *et al.* (2021) state that no studies have been conducted specifically on the age at maturity for the sunflower sea star, but estimate it to be at least five years based on the age of first reproduction for the ochre star (Menge 1975; Chia and Walker 1991).

Without additional information on the size at first maturity, fecundity, reproductive seasonality, and reproductive senescence of the sunflower sea star, and how these demographic parameters vary throughout the range of the species, it is impossible to accurately predict annual reproductive output of populations or to adequately evaluate resiliency and rebound potential in response to environmental perturbations. Indications from other sea stars, however, suggest that reproductively viable females can produce at least tens of millions of eggs annually, possibly for several decades. Under appropriate environmental conditions, this represents considerable reproductive and recruitment potential.

Sea stars may modify their behavior during spawning in ways that improve the chances of egg fertilization, including aggregating, modifying their positions and postures, and spawning synchronously (Strathmann 1987; Chia and Walker 1991; Dams *et al.* 2018). Although many sea stars appear to aggregate during spawning (Strathmann 1987; Minchin 1987; Chia and Walker 1991; Babcock and Mundy 1992; Raymond *et al.* 2007; Himmelman *et al.* 2008; Dams *et al.* 2018), it is uncertain whether sunflower sea stars do so. Kjerskog-Agersborg (1918) studied sunflower sea stars in Puget Sound at Bremerton, WA, and suggested that individuals migrated to shallower waters during the spawning season and were present in large aggregations at this time of year. A number of other sea stars move into shallow water during the spawning season, supporting that movement into shallow water may be an adaptive behavior that promotes fertilization (Babcock *et al.* 2000). Some fertilization rate modeling results for the crown-of-thorns sea star *Acanthaster* spp. (Babcock *et al.* 1994) indicate that shallower water increases fertilization rates relative to deeper water because of reduced dilution of gametes in waters shallower than 5 m (Babcock *et al.* 2000).

Many sea stars arch their bodies upward, remaining in contact with the substratum by the tips of their arms during spawning. This posture elevates the gonopores through which gametes are shed into the flow field (Galtsoff and Loosanoff 1939; Strathmann 1987; Minchin 1987; Chia and Walker 1991; Dams *et al.* 2018). Dams *et al.* (2018) used laboratory experimentation and theoretical modeling to show that an arched posture promoted downstream dispersion of gametes and was more effective than stars lying in the flat position. It is common knowledge that sunflower sea stars also arch their bodies upward in this characteristic spawning posture. Although we were unable to locate specific reference in the scientific literature, there are numerous photographs and depictions of sunflower sea stars assuming this spawning posture on the internet (*e.g., https://www.kuow.org/stories/scientists-race-to-rescue-world-s-fastest-sea-star-from-oblivion*).

Since released gametes (especially sperm) may remain viable for as little as two hours (Strathmann 1987; Benzie and Dixon 1994), many sea stars increase the chances of egg fertilization by spawning synchronously (Feder and Christensen 1966; Babcock and Mundy 1992; Babcock *et al.* 1994; Mercier and Hamel 2013). In many published observations of sea star spawning, males consistently spawned before females (Mercier and Hamel 2013). Even though synchronous spawning is necessary for successful fertilization to occur, synchronization must be accompanied by relatively close proximity for successful fertilization (Mercier and Hamel 2013). There is conflicting information regarding whether synchronous aggregative spawning is exhibited by the sunflower sea star, but evidence from ecologically similar sea star species and anecdotal observations for the sunflower sea star strongly suggest this is the case. If this is the case, when population abundance declines below levels that ensure contact of distributed eggs and sperm with one another, Allee effects may hinder population persistence and/or recovery (Lundquist and Botsford 2004; 2011). Standard population models predict that a reduction in adult density should be associated with a decrease in intraspecific competition leading to an increase in growth rate, survival, and gamete production. However, these advantages may be countered by decreases in the rate of successful fertilization among sparsely distributed individuals (Levitan 1995; Levitan and Sewell 1998; Gascoigne and Lipcius 2004). Fertilization success may be a limiting factor in reproduction, and hence recruitment. We did not find published data from directed studies of natural fertilization success in the sunflower sea star.

Several researchers have, with varying degrees of success, attempted to rear sunflower sea stars and describe early embryonic and larval development through to metamorphosis (Mortensen 1921; Greer 1962; Strathmann 1970; 1978; Chia and Walker 1991; Hodin *et al.* 2021). Greer (1962) reported that time from fertilization to metamorphosis for larvae from San Juan Islands, Washington, ranged from 60 to 70 days when reared at 10 to 12 °C. Strathmann (1978) reported that time from fertilization through to settling ranged from 90 to 146 days at natural local water temperatures (7 to 13 °C) encountered in the San Juan Islands, Washington, in the late 1960s. Hodin *et al.* (2021) reared sunflower sea stars from Washington at 9 °C and 14 °C and observed first spontaneous settlement of larvae at seven weeks when held at 10 to 11 °C. Peak metamorphosis occurred at eight weeks in larvae derived from Alaskan broodstock, compared to 11 weeks for larvae from Washington broodstock. Hodin *et al.* (2021) reported that larvae first became competent to metamorphose at seven weeks post-fertilization at 10 to 11 °C, compared to the nine weeks reported by Greer (1962) when reared at 10 to 12 °C. Together, these studies indicate that larval duration may be as short as seven weeks or as long as 21, and that temperature is a key parameter determining the extent of this period.

Unlike the pentaradial symmetry of adult sea stars, larvae are bilaterally symmetrical (Chia and Walker 1991). The bipinnaria larva is characterized by two bilaterally symmetrical ciliary bands and an open, functional gut (McEdward *et al.* 2002). Both the bipinnaria, and the later-stage brachiolaria, ingest diatoms and other single-celled algae, and may also utilize dissolved organic matter nutritionally (Chia and Walker 1991). Bipinnaria larvae of the sunflower sea star were estimated to form on the fifth (Greer 1962) or sixth day (Hodin *et al.* 2021) after fertilization.

To understand the population dynamics of the sunflower sea star on a range-wide basis it is crucial to develop an understanding of larval longevity and capacity for dispersal. Time from egg fertilization to metamorphosis for the sunflower sea star under various conditions has been described as 49 to 77 days (Hodin *et al.* 2021), 60 to 70 days (Greer 1962), and 90 to 146 days (Strathmann 1978). As noted by Gravem *et al.* (2021), broadcast spawning with a long pelagic larval duration has the potential for broad larval dispersal, especially in open coastal areas with few geographic barriers. Along more heterogeneous, complex shorelines like those found inside the Salish Sea or Southeast Alaska, however, complex flow patterns may result in localized entrainment of larval and reduce dispersal capacity.

Minimum and maximum dispersal periods based on laboratory studies of planktotrophic larvae reveal how varying environmental and nutritional conditions influence the extent of the planktonic period (Pechenik 1990). Basch and Pearse (1996) showed that sea star larvae grown in phytoplankton-rich conditions had greater survival, were in better condition, settled and metamorphosed sooner, and produced larger juveniles compared to larvae grown in low food concentrations. Planktotrophic larvae of many sea star species can delay metamorphosis in the absence of suitable settlement cues (Metaxas 2013), and are capable of long-range dispersal (Scheltema 1986; Metaxas 2013). Although mortality of sea star larvae during the planktonic larval stage has not been measured, it is expected to be high (Metaxas 2013), and it is likely that delaying metamorphosis would expose larvae to an additional period of predatory pressure (Basch and Pearse 1996) and stress associated with limited food availability. Strathmann (1978) found the maximum time to settlement in culture for sunflower sea star to be 21 weeks and emphasized that the duration of pelagic larval life is important in recruitment dynamics and, ultimately, to the distribution of a species.

Sea star larvae may respond to a suite of biological, chemical, and/or physical cues that induce metamorphosis and settlement, including the presence of coralline algae, microbial films, and kelp (Metaxas 2013). Hodin *et al.* (2021) state that competent sunflower sea star larvae will settle spontaneously, as well as in response to a variety of natural biofilms. Settlement is greatly enhanced when larvae are presented with a biofilm collected in the presence of adult sunflower sea stars, or if larvae are exposed to fronds of the articulated coralline alga, *Calliarthron tuberculosum*.

It is generally accepted that planktotrophic larvae are typically dispersed considerable distances away from adult populations and have little impact on recruitment to the natal habitat (Sewall and Watson 1993; Robles 2013). However, Sewell and Watson (1993) described a situation at the semi-enclosed bay of Boca del Infierno (Nootka Island, British Columbia) where larvae were entrained and settled within the adult habitat, contributing to the source population. During three years between 1987 and 1991, sunflower sea star recruits were observed on *Sargassum muticum* on the floor of the channel leading into the bay (Sewell and Watson 1993). In general, sea stars are thought to have relatively low annual recruitment punctuated by unusually strong settlement in some years (Sanford and Menge 2007), the so-called boom and bust cycle characteristic of a broad diversity of marine fishes and invertebrates with planktonic larval dispersal (*e.g.,* McLatchie *et al.* 2017; Schnedler-Meyer *et al.* 2018).

Larvae of sea stars are capable of regenerating lost body parts much like adults (Vickery and McClintock 1998; Vickery *et al.* 2002; Allen *et al.* 2018) and may also reproduce asexually through the process of larval cloning—budding off of tissue fragments that regenerate into complete larvae (Bosch *et al.* 1989; Rao *et al.* 1993; Jaeckle 1994; Knott *et al.* 2003). Recently, Hodin *et al.* (2021) reported that larvae of the sunflower sea star also have the capability to clone in a laboratory setting, describing cloning as "commonplace" in all larval cultures. The degree to which larval sunflower sea stars clone in nature may have profound implications for life history (*e.g.,* fecundity, dispersal distance), population dynamics, and population genetic structure (Knott *et al.* 2003; Balser 2004; Rogers-Bennett and Rogers 2008; Allen *et al.* 2018; 2019).

In a recent review of asexual reproduction in larval invertebrates, Allen *et al.* (2018) tabulated the potential benefits of larval cloning as: (1) increasing female fecundity without an apparent increase in resource allocation to reproduction; (2) increasing the likelihood that a member of a genet (*i.e.,* group of cloned individuals) survives; (3) increasing the probability that a member of a genet will locate a suitable settlement site by sampling a greater geographic area; and (4) reducing the genet's susceptibility to predation and other loss by increasing the number and decreasing the size of propagules. On the other hand, Allen *et al.* (2018) listed likely costs associated with larval cloning as: (1) a decrease in larval feeding rate during fission; (2) a decrease in larval growth rate; (3) an increase in the time to metamorphosis; and (4) a decrease in juvenile size. Larval cloning has the potential to alter several aspects of sunflower sea star life history by increasing actualized fecundity, larval dispersal distance, and chances of successful settlement of a larva or at least its genetically identical clone (Bosch *et al.* 1989; Balser 2004; Rogers-Bennett and Rogers 2008; Allen *et al.* 2019). Balser (2004) noted that cloning serves to increase female fecundity to >1 juvenile per egg, altering recruitment intensity. Without additional information about environmental impacts on cloning rate, this lack of a one-to-one relationship between female productivity and realized recruitment potential complicates estimation of stock-recruit relationships. Allen *et al.* (2019) emphasized that ignoring the impacts of planktonic cloning meant that both realized reproductive output and larval dispersal period had been underestimated in prior population modeling efforts for sea stars (Rogers-Bennett and Rogers 2008). To date, evidence of the existence of sexually mature sea star individuals in wild populations that originated from cloned larvae is lacking for any species (Knott *et al.* 2003), including the sunflower sea star. Thus, despite a demonstrated capacity to clone as larvae, estimates of female fecundity considered in the draft status review report (Lowry *et al.* 2022) are limited to gross estimates of egg production on a seasonal basis, which, as noted above, are tenuous at best.

No studies have been conducted to establish natural growth rates throughout the lifespan of the sunflower sea star, due in part to the difficulty of tagging and effectively tracking individuals. The IUCN assessment for the sunflower sea star lists several observations of juvenile growth rates from anecdotal observations and laboratory studies as being between 3 and 8 cm/yr, and 2 cm/yr for mid-sized individuals (Gravem *et al.* 2021). Hodin *et al.* (2021) reared post-metamorphic, laboratory-cultured sunflower sea stars and the fastest growing individuals were able to reach a diameter of 3 cm in 288 days (about 9.5 months) post-settlement. Juveniles reared by Hodin *et al.* (2021) grew slowly for several months after settlement, but grew faster after they reached about 10 cm in diameter, at which time they could feed on live juvenile bivalves. Laboratory estimates may not be entirely representative of growth rates in the field because sea star growth is affected by water temperature and food availability (Gooding *et al.* 2009; Deaker *et al.* 2020; Dealer and Byrne 2022). Sea star growth rate also generally decreases with increasing size of individuals (Carlson and Pfister 1999; Keesing 2017). Some sea stars can persist for long periods with little or no food (Nauen 1978; Deaker *et al.* 2020; Byrne *et al.* 2021), potentially complicating estimates of age based on size and resulting in episodic growth only when resources are adequate to exceed base metabolic needs.

In one of the few published reports of sunflower sea star growth under pseudonatural conditions, Miller (1995) described growth of juveniles found on settlement collectors (*i.e.*, Astroturf-coated PVC tubes) on the Oregon coast. When fed crushed prey, juveniles grew from a mean arm length (AL) of 0.41 mm at first sampling, to a mean AL of 3.65 mm at 63 days, and 5 to 6 mm AL at 99 days. Thus, juveniles increased in size by a factor of nearly nine times after two months and up to 14 times after three months from sampling (Miller 1995).

In response to the call for public comments on our 90-day finding for the petition to list the sunflower sea star under the ESA (86 FR 73230; December 27, 2021), we received a dataset demonstrating growth of putative cohorts of juvenile sunflower sea stars from Holmes Harbor on the east side of Whidbey Island, in the Southern Salish Sea, Washington (K. Collins, pers. comm., March 20, 2022). During repeated SCUBA-based sampling of the size distribution of populations of sunflower sea stars at several index sites between March of 2020 and 2022, recruitment pulses of individuals could be identified from frequency of occurrence data. Between March of 2020 and March of 2021, the average diameter of one such group of juvenile sunflower sea stars increased 7.99 cm, from ~9 to 17 cm. This annual growth rate aligns with the rapid growth period identified by Hodin *et al.* (2021), concomitant with the ability to consume small bivalves. While this estimate is for one small population in the Salish Sea and is cohort-based rather than based on tracking target individuals, it provides insight into the growth of juvenile sunflower sea stars that is not available elsewhere.

The longevity of sunflower sea stars in the wild is unknown, as is the age at first reproduction (as noted above) and the period over which a mature individual is capable of reproducing, but these parameters are needed to calculate generation time. It is also unknown if, or how much, any of these crucial life history parameters vary across the range of the species. The IUCN assessment for the sunflower sea star used a generic echinoderm equation to estimate generation times as 20.5 to 65 years or 27 to 37 years, depending on maximum longevity (reaching maximum size observed of 95 to 100 cm diameter) or more typical longevity (time to reach 50 cm diameter) estimated from two different growth models (Gravem *et al.* 2021). These generation time figures utilized an estimated age at first reproduction of five years, based on the ochre star and other species, as this information is not available for the sunflower sea star (Gravem *et al.* 2021).

Diet and Feeding

Larval and pre-metamorphic sunflower sea stars are planktonic feeders and no data exist to suggest a prey preference at this stage. The diet of adult sunflower sea stars generally consists of benthic and mobile epibenthic invertebrates, including sea urchins, snails, crab, sea cucumbers, and other sea stars (Mauzey *et al.* 1968; Shivji *et al.* 1983), and appears to be driven largely by prey availability. Sea urchins were the major dietary component in the intertidal regions along the outer coast of Washington in a study by Mauzey *et al.* (1968). For sunflower sea stars inhabiting kelp forests in central California, however, 79 percent of the diet was gastropods, and only four sea urchins were found in the guts of 41 adults (Herrlinger 1983). Sunflower sea stars also feed on sessile invertebrates, such as barnacles and various bivalves (Mauzey *et al.* 1968). Mussels are a common prey in intertidal regions in Alaska (Paul and Feder 1975). Clams can also constitute a major proportion of their diet, with up to 72 percent coming from clams at subtidal sites within Puget Sound (Mauzey *et al.* 1968). Adults excavate clams from soft or mixed-substrate bottoms by digging with one or more arms (Smith 1961; Mauzey *et al.* 1968). Sunflower sea stars locate their prey using chemical signals in the water and on substrate, and may show preference for dead or damaged prey (Brewer and Konar 2005), likely due to reduced energy expenditure associated with catching and subduing active prey; thus they occasionally scavenge fish, seabirds, and octopus (Shivji *et al.* 1983).

Population Demographics and Structure

Prior to the onset of the coast-wide sea star wasting syndrome (SSWS) pandemic in 2013 (see evaluation of threats below), directed population monitoring for the sunflower sea star was haphazard and typically the result of short-term research projects rather than long-term monitoring programs. Such efforts were rarely focused on the sunflower sea star itself, but it was often included as one component of the local invertebrate assemblage, and generally it was secondary to the primary species of interest. Indigenous peoples occupying lands along the Pacific Coast of North America from Alaska to California have long known of the sunflower sea star, have included the species in artistic works, and have recognized the important ecological role it plays. However, no oral histories or other traditional ecological knowledge that directly addressed long-term population distribution or abundance could be found. In response to the 90-day finding on the petition to list the sunflower sea star (86 FR 73230; December 27, 2021), several First Nation and tribal entities contacted us to provide recent monitoring data, which was integrated into the draft status review report as much as possible (Lowry *et al.* 2022). Most of the datasets lacked pre-2013 (*i.e.*, before the SSWS pandemic) occurrence records, however, and could not be used to quantitatively evaluate trends in abundance or density relative to baseline values.

Recent descriptions of sunflower sea star distribution and population declines by Harvell *et al.* (2019), Gravem *et al.* (2021), and Hamilton *et al.* (2021) relied on datasets gathered either exclusively or predominantly during the 21st century and, in some cases, as a direct response to losses due to SSWS. The most intense loss occurred over just a few years from 2013 through 2017, generally commencing later in more northern portions of the range, and impacts varied by region. Hence, our understanding of the historical abundance of the sunflower sea star is patchy in both time and space, with substantial gaps.

Summary data presented in Gravem *et al.* (2021) indicate that prior to the 2013 through 2017 SSWS outbreak the sunflower sea star was fairly common throughout its range, with localized variation linked to prey availability and various physiochemical variables. Starting in 2012, Konar *et al.* (2019) assessed rocky intertidal populations in the Gulf of Alaska and described sunflower sea stars prior to the 2016 wasting outbreak as "common" toward the northwest part of the species' range in the Katmai National Park and Preserve near Kodiak Island, AK (0.038/m^2 in 2012 and 0.048/m^2 in 2016, respectively). Abundances during this pre-pandemic period varied geographically, from infrequent in Kachemak Bay (<0.005 m^2), to fairly common in the Kenai Fjords National Park (~0.075/m^2), and common in western Prince William Sound (average 0.233/m^2) (Konar *et al.* 2019). In subtidal rocky reefs near Torch Bay, Southeast Alaska, densities were high (0.09 ± 0.055/m^2) in the 1980s (Duggins 1983). In Howe Sound, near Vancouver, British Columbia, densities were high at 0.43 ± 0.76/m^2 in 2009 and 2010 before the SSWS pandemic (Schultz *et al.* 2016). Montecino-LaTorre *et al.* (2016) found that sunflower sea star abundance averaged 6 to 14 individuals per roving diver survey throughout much of the Salish Sea from 2006 through 2013. In deep water habitats off the coasts of Washington, Oregon, and California, 2004 through 2014 pre-outbreak biomass averaged 3.11, 1.73, and 2.78 kg/10 ha, respectively (Harvell *et al.* 2019). In 2019, a remotely operated vehicle survey of the Juan de Fuca Canyon encountered a number of large sunflower sea stars at depths ranging from 150 to 350 m (OCNMS 2019). While population connections between these sea stars and those in shallow water remain unknown, this suggests that deep waters may serve as a biomass reservoir for the species (J. Waddell, Olympic Coast National Marine Sanctuary, pers. comm., March 15, 2022).

Along the north and central California coastline, average population densities were 0.01–0.12/m^2 prior to 2013 (Rogers-Bennett and Catton 2019). The oldest density records come from kelp forests near central California in Monterey Bay, where densities were 0.03/m^2 in 1980 and 1981 (Herrlinger 1983). More recently in central California, densities were even lower and fluctuated from 0.01–0.02/m^2 between 1999 and 2011 (Smith *et al.* 2021). In southern California, sites in the Channel Islands have been studied extensively, and from 1982 through 2014 densities ranged from 0 to 0.25/m^2 (Bonaviri *et al.* 2017), from 1996 through 1998 they were 0 to 0.02 m^2 (Eckert 2007), from 2003 through 2007 they were 0 to 0.07m^2 (Rassweiler *et al.* 2010), and from 2010 through 2012 they were ~0.10 to 0.14/m^2 (Eisaguirre *et al.* 2020).

The pattern of decline by latitude as a consequence of the SSWS pandemic in 2013 (see evaluation of threats below) is striking. Hamilton *et al.* (2021) noted a 94.3 percent decline throughout the range of the sunflower sea star after the outbreak of SSWS. The 12 regions defined by Hamilton *et al.* (2021) encompass the known range of the sunflower sea star, and each region exhibited a decline in density and occurrence from approximately 2013 through 2017, with populations in the six more northern regions characterized by less severe declines (40 to 96 percent declines) than those in the six regions spanning from Cape Flattery, WA, to Baja, MX, where the sunflower sea star is now exceptionally rare (99.6 to 100 percent declines). Furthermore, while anecdotal observations indicate recruitment continues in the U.S. portion of the Salish Sea, British Columbia, and Alaska, few of these juveniles appear to survive to adulthood (A. Gehman, University of British Columbia and the Hakai Institute, pers. comm., February 16, 2022). We are not aware of any observations of sunflower sea star recruits or adults in California or Mexico since 2017 despite continued survey effort in these areas.

There are not, to date, any range-wide or regional assessments of systematic variation in life history parameters, morphological characteristics, genetic traits, or other attributes that can be used to delineate specific populations of sunflower sea stars. As such, we have no direct biological data to establish that the species is anything but a single, panmictic population throughout its range. As habitat generalists that use a wide variety of substrates over a broad depth range, and dietary generalists that consume diverse prey based largely on prey availability and encounter rate, differentiation of subpopulations is not expected to be driven by strong selection for particular environmental needs. In the 2020 IUCN status assessment report (Gravem *et al.* 2021), putative population segments were identified largely based on a combination of legal and geographic boundaries/barriers and data provided in response to a broad request distributed to natural resource managers and academic researchers. For instance, data from both trawl and SCUBA diving surveys were considered together to describe population trends in a region defined as "Washington outer coast," which spanned from Cape Flattery to the Washington-Oregon border.

Because sunflower sea stars are relatively sessile in the settled juvenile through adult life stages, any population structuring is likely attributable to dispersion during the pelagic larval phase. This is a common feature of broadcast spawning, benthic, marine organisms, and population breaks in such organisms are typically associated with strong biogeographic features where current flows diverge or stop (*i.e.*, Queen Charlotte Sound, Point Conception), if such features exist. Within a given biogeographic region, such organisms typically exhibit either genetic homogeneity for species with prolonged pelagic larval phases or, for species with shorter pelagic larval duration, a stepping-stone dispersal resulting in isolation-by-distance. Within the historical range of the sunflower sea star, there are two major biogeographic regions (Longhurst 2007), the "Alaska Coastal Downwelling Province" and the "California Current Province." These regions are essentially formed by the bifurcation of the North Pacific Current into the northward-flowing Alaska Current and the southward-flowing California Current. This bifurcation occurs in the vicinity of Vancouver Island, though the exact location varies with shifting climatic conditions and bulk water transport processes, with a transition zone between Queen Charlotte Sound and Cape Flattery (Cummins and Freeland 2007).

For some echinoderm species that have been more thoroughly examined, regional variation in phenotypic and genetic traits along the west coast of North America have been documented. Bat stars (*Patiria miniata*) largely overlap with the sunflower sea star in geographic range and depth distribution, and share similar planktonic larval duration, so can potentially be used as a proxy to make demographic inferences. Keever *et al.* (2009) used a combination of mitochondrial and nuclear markers to study bat stars range-wide and provided support for two genetically distinct populations, essentially split across Longhurst's (2007) biogeographic provinces. Within the California Current

Province there was little detectable genetic structure, but within the Alaska Coastal Downwelling Province there was a high degree of structure, potentially as a consequence of the geographic complexity within this region as compared with the California Coast Province. Gene flow simulations showed that larvae of the bat star don't disperse far despite a relatively long pelagic larval duration (Sunday *et al.* 2014). The red sea urchin (*Strongylocentrotus franciscanus*) also overlaps in range, depth, and duration of planktonic dispersal with sunflower sea star but shows no clear signal of genetic partitioning (Debenham *et al.* 2000) throughout its range. Similarly, the ochre star exhibits similar life history parameters but shows no genetic partitioning (Harley *et al.* 2006). Overall, the lack of demonstrated genetic structure in these co-occurring echinoderm species suggests that sunflower sea stars may also lack population structure, but no genetic studies currently exist that would allow us to confirm or refute this assumption.

Assessment of Extinction Risk

Using the best available scientific and commercial data relevant to sunflower sea star demography and threats, the SRT undertook an assessment of extinction risk for the species. The ability to measure or document risk factors and quantify their explicit impacts to marine species is often limited, and quantitative estimates of abundance and life history information are sometimes lacking altogether. Therefore, in assessing extinction risk of this data-limited species, we relied on both qualitative and quantitative information. In previous NMFS status reviews, assessment teams have used a risk matrix method to organize and summarize the professional judgment of members. This approach is described in detail by Wainwright and Kope (1999) and has been used in Pacific salmonid status reviews, as well as in reviews of various marine mammals, bony fishes, elasmobranchs, and invertebrates (see *https://www.nmfs.noaa.gov/pr/species/* for links to these reviews). In the risk matrix approach, the condition of a species is summarized according to four viable population factors: abundance, growth rate/productivity, spatial structure/connectivity, and diversity (McElhany *et al.* 2000). These viable population factors reflect concepts that are well-founded in conservation biology and that, individually and collectively, provide strong indicators of extinction risk. Employing these concepts, the SRT conducted a demographic risk analysis for the sunflower sea star to determine population viability. Likewise, the SRT performed a threats assessment by scoring the severity of current threats to the species and their likely impact on population status into the foreseeable future. The summary of demographic risks and threats obtained by this approach was then considered to determine the species' overall level of extinction risk, ranked either low, moderate, or high, both currently and in the foreseeable future. Further details on the approach and results are available in Lowry *et al.* (2022).

For the assessment of extinction risk for the sunflower sea star, the "foreseeable future" was considered to extend out 30 years based on several lines of evidence, though numerous assumptions had to be made due to missing information. Limited data are available regarding sunflower sea star longevity, age at sexual maturity, size at sexual maturity, fecundity, reproductive life span, spawning frequency, and other fundamental biological attributes. Further, the degree to which these parameters might vary over the range of the species is unknown. Gravem *et al.* (2021) estimated the generation time of the sunflower sea star to vary between 20.5 and 65 years based on a generalized echinoderm model, but used an estimate of 27 to 37 years for the 2020 IUCN assessment. Monitoring data for the sunflower sea star at locations spread throughout its range documented extremely rapid, dramatic declines from 2013 to 2017 as a consequence of SSWS. Despite considerable research since, the causative agent of SSWS remains elusive, as does the environmental trigger or triggers that led to the pandemic. Extending and augmenting the analysis of Gravem *et al.* (2021), Lowry *et al.* (2022) demonstrated that if post-pandemic negative trends in population abundance continue, extinction risk is high in the immediate and foreseeable future. If pre-pandemic population growth rates resume, however, the likelihood of long-term persistence is moderate to high, depending on region. Which of these scenarios is more likely depends on disease resistance, current local population dynamics, and a myriad of environmental factors affecting both the sunflower sea star and the SSWS agent(s). If individuals that survived the pandemic are able to successfully reproduce over the next several years, and ocean conditions are adequate to support larval survival and settlement, a substantive recruitment pulse could result. Whether the causative agent of SSWS exists in an environmental or biological reserve, however, is also unknown. If it does, any recruitment pulse could be short lived and individuals may not survive to reproduce themselves. There is a high level of uncertainty regarding potential outcomes, and predictive capacity is limited as a consequence of the unique combination of ocean conditions and disease prevalence in recent years.

After considering the best available information on sunflower sea star life history (including its mean generation time), projected abundance trends, likelihood of a resurgence of SSWS to pandemic levels, and current and future management measures, the SRT concluded that after 30 years uncertainty in these factors became too great to reliably predict the biological status of the species. Though potential threats like nearshore habitat degradation and anthropogenic climate change can be projected further into the future, the SRT concluded that the impacts of these threats on the sunflower sea star could not be adequately predicted given the behavioral patterns of the species with regard to habitat use and diet. Whether population segments occupying deep waters will fare better than those in the shallows, and to what degree these populations are linked, cannot be adequately predicted given limited knowledge of sunflower sea star biology and demography. Given the demonstrated capacity of SSWS to kill billions of individuals across the entire range of the species over just a few years, the SRT felt that reliably assessing the effects of additional threats on species viability beyond the temporal range of 30 years was not possible.

Demographic Risk Analysis

Methods

The SRT reviewed all relevant biological and commercial data and information for the sunflower sea star, including: current abundance relative to historical abundance estimates, and trends in survey data; what is known about individual growth rate and productivity in relation to other species, and its effect on population growth rate; spatial and temporal distribution throughout its range; possible threats to morphological, physiological, and genetic integrity and diversity; and natural and human-influenced factors that likely cause variability in survival and abundance. Each team member then assigned a risk score to each of the four viable population criteria (abundance, productivity, spatial distribution, and diversity) throughout the whole of the species' range. Risks for each criterion were ranked on a scale of 0 (unknown risk) to 3 (high risk) using the following definitions:

0 = *Unknown:* Information/data for this demographic factor is unavailable or highly uncertain, such that the contribution of this factor to the extinction risk of the species cannot be determined.

1 = *Low risk:* It is unlikely that the particular factor directly contributes significantly to the species' current risk of extinction, or will contribute significantly in the foreseeable future (30 years).

2 = *Moderate risk:* It is likely that the particular factor directly contributes significantly to the species' current risk of extinction, or will contribute significantly in the foreseeable future (30 years), but does not in itself currently constitute a danger of extinction.

3 = *High risk:* It is highly likely that the particular factor directly contributes significantly to the species' current risk of extinction, or will contribute significantly in the foreseeable future (30 years).

Team members were given a template to fill out and asked to score each criterion's contribution to extinction risk. Scores were provided to the team lead, anonymized, then shared with the entire team, which discussed the range of perspectives and the supporting data/information upon which they were based. Team members were given the opportunity to revise scores after the discussion, if they felt their initial analysis had missed any pertinent data discussed in the group setting. Final scores were reviewed and considered, then synthesized, to arrive at the overall demographic risk determination from the team. Further details are available in Lowry *et al.* (2022).

Abundance

Severe declines in nearly all available datasets, range-wide from 2013 through 2017 are readily apparent, with little evidence of recent recruitment or rebound (Gravem *et al.* 2021; Lowry *et al.* 2022). While variability in abundance estimates was high prior to the SSWS pandemic and boom/bust cycling was apparent in many areas, detection rates have been very low since approximately 2015 in the majority of time series datasets. Datasets from the Oregon and California coasts are notable because they report several years of regular observation of sunflower sea stars leading up to 2013, followed by several years of absence at the same index sites. In locations where individuals continued to be detected after the pandemic, like in northern Oregon, density decreased by an order of magnitude or more. Data providers for these time series categorize the near or total loss of sunflower sea stars in their survey area as local or functional extirpation, but other researchers and the public have reported juveniles in several of these areas (*e.g.*, the Channel Islands), demonstrating that some reproduction and settlement is occurring. In areas where adults have not been detected for several years, the potential for deleterious stochastic events, such as marine heat waves, to destroy what remains of the population is likely to be considerably increased. Abundance prior to the SSWS pandemic was substantially greater in northern portions of the range from Alaska to the Salish Sea, and declines in these areas were less pronounced (Gravem *et al.* 2021; Lowry *et al.* 2022).

The current range-wide (*i.e.*, global) population estimate for the sunflower sea star is nearly 600 million individuals, based on a compilation of the best available science and information (Gravem *et al.* 2021). While substantial, this represents less than 10 percent of the estimated abundance prior to 2013 and likely reflects an even greater decrease in biomass due to the loss of adults from SSWS. However, there is considerable uncertainty in this global abundance estimate and in regional estimates that contribute to it. Low sampling effort prior to the SSWS pandemic, depth-biased disparities in data richness, inadequate species-specific documentation of occurrence, and missing information about several crucial life history parameters all contribute to this uncertainty. While confidence is relatively high in estimates from more southerly, nearshore areas that are well-sampled via SCUBA, the majority of the species' range consists of deep, cold, and/or northern waters that are less well sampled. How segments of the population in these poorly sampled areas contribute to and are connected with the overall health and stability of the species remains largely unknown. Sunflower sea stars in these areas are less susceptible to impacts from nearshore stressors and could serve as source populations to support population rebound, but evidence to support this role is lacking. Based on the broad geographic range over which the remaining population is spread, the generalist nature of the sunflower sea star with regard to both habitat use and diet, and the possibility that deep-water individuals may serve as source populations to bolster recovery, the team concluded that the current state of the abundance criterion was a moderate factor in affecting extinction risk in the foreseeable future.

Productivity

Little is known about the natural productivity of the sunflower sea star on both an individual and population basis. Lack of information about growth rate, longevity, age at maturity, fecundity, natural mortality, the influence of larval cloning, and other fundamental biological attributes requires that broad assumptions be applied and proxy species used to inform estimates on both regional and range-wide bases. Regardless of the values of nearly all of these parameters, however, the loss of approximately 90 percent of the global population of the sunflower sea star from 2013 through 2017 is likely to have had profound impacts on population-level productivity. The standing crop of individuals capable of generating new recruits has been decreased, possibly to levels where productivity will be compromised on a regional or global basis. The combined factors of spatial distribution of individuals across the seascape and ocean conditions are crucial to dictating whether productivity is sufficient to allow population rebound. Broadly dispersed individuals may lack the ability to find mates, further reducing realized productivity despite abundance being high enough to theoretically result in population persistence.

As a broadcast spawner with indeterminate growth, traits shared with many other echinoderms, the capacity for allometric increases in fecundity and high reproductive output certainly exists in the sunflower sea star. Hodin *et al.* (2021) noted that gonads are small in sunflower sea stars compared to other sea stars but also documented prolonged periods over which spawning apparently occurs (*i.e.*, gonads are ripe). If the SSWS pandemic resulted in the loss of the large, most reproductively valuable individuals across both nearshore and deep-water habitats, it could take a decade or more for sub-adults to mature, settlement to occur at detectable levels, and population rebounds to be documented. There is evidence in some areas that recruitment has occurred, demonstrating that local productivity is still occurring, but it may be years before these individuals reach maturity and spawn. The ongoing threat of another SSWS pandemic dictates that caution is warranted when predicting population growth rate into the foreseeable future.

Provided reproduction continues to occur, even on a local basis, the prolonged planktonic period of larval sunflower sea stars affords the opportunity for substantial dispersal prior to settlement. During this period, however, larvae are at the mercy of prevailing currents, temperature variation, and a suite of biophysical variables that affect survival. Even if populations maintain relatively high levels of productivity, recent conditions in the northeast Pacific Ocean have not been favorable to larval survival for many species due to repeated marine heat waves, falling pH, and localized oxygen minimum zones. Additionally, given the predominant flow regime along the Pacific West Coast of North America, propagules are expected to be carried both northward and southward from British Columbia following the North Pacific Current as it bifurcates into the Alaska and California Currents, respectively. Given the distance larvae must travel with the currents, populations in British Columbia are not expected to contribute markedly to repopulation in the southern portion of the range off Oregon, California, and Mexico. While the Davidson Countercurrent and California Undercurrent may seasonally carry propagules northward from Mexico and California (Thomas and Krassovski 2010), abundance of the sunflower sea star in this portion of the range is not currently likely to be high enough to serve as a source population to areas off Washington, Oregon, or northern California. Studies of connectivity across the range of the sunflower sea star will be crucial to evaluating how large-scale population patterns are affected by local and regional productivity in the future.

Taking into account the many unknowns about life history, population level reproductive capacity, and functional implications of environmental conditions on population connectivity in the foreseeable future, the productivity criterion was scored as a moderate contributor to overall extinction risk over the foreseeable future, though there was considerable variation in individual team member scores. Depensatory impacts from abundance declines have likely decreased productivity on a local and regional scale, but the adults that remain are assumed to live long enough that opportunities to mate will manifest in time, provided they are able to find one another and mate. Until more is known about the underlying biology of the species, this parameter, and its effects on long-term viability, will remain poorly defined.

Spatial Distribution and Connectivity

Despite substantial population declines from 2013 through 2017, sunflower sea stars still occupy the whole of their historic range from Alaska to northern Mexico, though in nearshore areas from the outer coast of Washington to Mexico the species is now rare where it was once common (Gravem *et al.* 2021; Lowery *et al.* 2022). Natural resource managers and researchers in the contiguous United States consider several local populations off Oregon and California to be functionally extirpated, but reports of newly settled juveniles and occasional adults in these regions demonstrate continued occupancy (Gravem *et al.* 2021; Lowery *et al.* 2022). With so few individuals, a new wave of SSWS or other catastrophic event could eliminate the species in these areas. However, the lack of adequate sampling of deep waters and patchy encounter reporting in bottom-contact fisheries with a high likelihood of interaction (*e.g.*, crustacean pot/trap fisheries) introduces sufficient uncertainty to preclude stating that sunflower sea stars have been extirpated throughout this southern portion of their range.

Spatial distribution and connectivity are integrally related with the abundance and productivity criteria. Species occurrence, density, habitat use, and intraspecific interaction rate, alongside environmental parameters, ultimately determine population productivity and abundance. As a habitat generalist with broad resilience to physiochemical environmental variables, the sunflower sea star utilizes most available benthic habitats from the nearshore down to several hundred meters deep throughout its range. Loss of over 90 percent of the population in southern portions of the range almost certainly resulted in population fragmentation, but the only areas where data exist to confirm this are shallow, SCUBA-accessible habitats. Kelp forests and rocky reefs, in particular, are well sampled and may represent key habitats for the sunflower sea star, but regular occurrence on mud, sand, and other soft-bottom habitats is also well documented. Undersampled, deep-water habitats represent the majority of suitable habitat for the sunflower sea star by area, however, additional effort is needed to characterize both how individuals in these waters are distributed and how they are connected with populations in shallow waters. Less accessible nearshore areas, largely those associated with sparsely populated areas, also suffer from undersampling.

Direct evidence to assess the connectivity of sunflower sea star populations at various geographic scales is lacking. Without meristic, morphological, physiological, and/or genetic studies to demonstrate similarities or differences among population segments linkages cannot be adequately evaluated. Broad assumptions can be made about larval distribution as a consequence of prevailing flow patterns, but evidence both for and against connections over large geographic scales for echinoderm populations on the Pacific Coast exist. Population declines associated with the SSWS pandemic were severe enough that historic patterns of spatial distribution and connectivity could have been obliterated in the last decade, and may continue to change into the foreseeable future.

After taking into account the best available information on both the historic and present spatial distribution of the sunflower sea star, spatial distribution was determined to have a moderate contribution to extinction risk. This was largely due to evidence of population fragmentation in nearshore areas and several data series demonstrating very low abundance across broad portions of the range. Connectivity could not be adequately assessed due to a lack of data.

Diversity

Systematic comparisons of morphology, life history, behavior, physiology, genetic traits, and other aspects of diversity do not exist for the sunflower sea star. While some authors note that animals in the northern portion of the range grow to a large diameter and mass, this general statement is not supported by data. As a result of this lack of information, adequately evaluating the impact of this parameter on extinction risk is difficult. Data from proxy species, such as the ochre star, demonstrate that variation in physical characteristics such as color can be both genetically and ecologically controlled in sea stars (Harley *et al.* 2006; Raimondi *et al.* 2007). While examples exist of echinoderm species with both substantial population structuring and a complete lack of population structure on the West Coast, where the sunflower sea star falls along this spectrum could not be determined due to the lack of fundamental biological knowledge pertinent to population dynamics. As a result, this criterion was determined to have an unknown contribution to overall extinction risk.

Threats Assessment

Methods

As noted above, section 4(a)(1) of the ESA requires the agency to determine whether the species is endangered or threatened because of any one, or a combination of, a specific set of threat factors. Similar to the demographic risk analysis, SRT members were given a template to fill out and asked to rank each threat in terms of its contribution to the extinction risk of the species throughout the whole of the species' range. Specific threats falling within the section 4(a)(1) categories were identified from sources included in the status review report, and included as line items in the scoring template (Lowry *et al.* 2022). Below are the definitions that the Team used for scoring:

0 = *Unknown:* The current level of information is insufficient for this threat, such that its contribution to the extinction risk of the species cannot be determined.

1 = *Low:* It is unlikely that the threat is currently significantly contributing to the species' risk of extinction, or will significantly contribute in the foreseeable future (30 years).

2 = *Moderate:* It is likely that this threat will contribute significantly to the species' risk of extinction in the foreseeable future (30 years), but does not in itself constitute a danger of extinction currently.

3 = *High:* It is highly likely that this threat contributes significantly to the species' risk of extinction currently.

The template also included a column in which team members could identify interactions between the threat being evaluated and specific demographic parameters from the viable population criteria analysis, as well as other section 4(a)(1) threats.

Scores were provided to the team lead, anonymized, and then the range of perspectives and the supporting data/information upon which they were based was discussed. Interactions among threats and specific demographic parameters, or other threats, were also discussed to ensure that scoring adequately accounted for these relationships. Team members were then given the opportunity to revise scores after the discussion if they felt their initial analysis had missed any pertinent data discussed in the group setting. Scores were then reviewed, considered, and synthesized to arrive at an overall threats risk determination. Results of this threats assessment are summarized below, and further details are available in Lowry *et al.* (2022).

The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range

The sunflower sea star is a habitat generalist known to occur in association with a broad diversity of substrate types, grades of structural complexity, and biogenic habitat components. Habitat degradation and modification in nearshore areas of the Pacific Coast as a consequence of direct human influence is largely concentrated in urbanized centers around estuaries and embayments, with considerable tracts of sparsely populated, natural shoreline in between. This is especially true of the northern portion of the range. In urbanized areas, nearshore modification to accommodate infrastructure has dramatically changed the available habitat over the last two hundred years. The relative importance of specific habitats to the range-wide health and persistence of the sunflower sea star is difficult to quantify, however, because suitable habitat occurs well beyond the depth range where most sampling occurs. Human impacts on nearshore habitats and species of the Pacific Coast have long been recognized, and marine protected areas, sanctuaries, and other place-based conservation measures have been created in a variety of jurisdictions in recent decades. While these measures have not explicitly targeted the sunflower sea star, many of them are centered on sensitive habitats (*e.g.,* kelp forests) and provide protections to the ecosystem at large, including sunflower sea stars and their prey. Under current nearshore management practices, the sunflower sea star has persisted in urban seascapes at apparently healthy population levels until very recently, when SSWS resulted in the death of 90 percent or more of the population. As a result, the SRT determined that nearshore habitat destruction or modification was a low-level contributor to overall extinction risk (Lowry *et al.* 2022), although systematic sampling is needed to establish whether certain habitat types are critical to specific life stages or behaviors for the sunflower sea star.

Sunflower sea stars also occur on benthic habitats to depths of several hundred meters, and anthropogenic stressors affecting these offshore waters are markedly different from those affecting the nearshore. Quantifying impacts to sunflower sea star habitat in deeper waters is more complicated, however, and less information is available to support a rigorous evaluation. Fishing with bottom-contact gear, laying communications or electrical cables, mineral and oil exploration, and various other human activities have direct influence on benthic habitats in offshore waters of the North Pacific Ocean. The activities are highly likely to interact with sunflower sea stars at some level, but data are lacking regarding both the distribution of individuals in these deeper waters and impacts from particular stressors. As a result, the SRT determined that effective assessment of the contribution of deep-water habitat modification or destruction on overall extinction risk of the species could not be conducted. Geographic input of all potential stressors in these deep waters is likely to be small relative to the documented range of the sunflower sea star and the SRT determined that the species' adaptability and resilience are unlikely to make habitat impacts in these areas a substantial threat (Lowry *et al.* 2022).

Curtailment of the range of the sunflower sea star has not yet been demonstrated, despite the fact that, since the SSWS pandemic, the species has become rare from the Washington coast south to California, areas where it once was common. The total population estimate for this region still stands at over five million individuals (Gravem *et al.* 2021) and their range north of Washington is vast. Population fragmentation as a consequence of dramatic losses in abundance could result in range curtailment in the foreseeable future, but occasional reports of juvenile sunflower sea stars at locations along the West Coast as far south as the Channel Islands demonstrate that local extirpation has not yet occurred. If juveniles do not mature and successfully reproduce because of a resurgence of SSWS to pandemic levels, or some other factor, a substantial reduction in distribution could occur at the southern extent of the currently documented range. A minority opinion within the SRT was that range curtailment has already occurred from Neah Bay, WA, southward and that remnant populations would soon be eliminated by natural demographic processes.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

There are no substantial current or historical fisheries directed at the sunflower sea star, but recreational harvest is allowed or permitted in Alaska, British Columbia, California, and Mexico and occurs at unquantified levels. Whether collected individuals are held for a short period before being released or permanently removed from the population is unknown. Impacts from recreational harvest cannot be evaluated because data are not available on either an aggregate or species-specific basis; however, market drivers for this species are minimal and human consumption is not known to occur. As a result, the SRT determined that recreational harvest impacts are a minor factor affecting extinction risk. Recreational harvest and trade may become a greater concern in the foreseeable future in areas where abundance levels are extremely low or declining. Additional regulations prohibiting retention could offset impacts from this potential threat.

Fishery bycatch impacts to the sunflower sea star are a low-level concern for a variety of fisheries that use bottom-contact gear. This includes fisheries for benthic fishes and invertebrates that employ trawls, pots, traps, nets, and, to a limited degree, hook-and-line. Information to quantify the encounter rate in specific fisheries is largely lacking, as are data demonstrating direct impacts of these encounters, and frequent aggregation of all sea star catch into a single reporting category precludes a species-specific assessment. That said, these potential risks are offset by the following observations: (1) the majority of commercial trawl fisheries occur in waters outside of preferred sunflower sea star depth zones (<25 m or 82 ft), based on the information regarding highest documented densities (Gravem *et al.* 2021); and (2) sunflower sea stars are anecdotally reported as being resilient to handling stress during regular fishing operations, though post-release monitoring is not reported in the literature. Post-release, handling-related stress could exacerbate symptoms of SSWS or increase susceptibility to other sources of mortality. This could make handling during fisheries a greater threat in regions where population abundance is especially low, such as from coastal Washington to the southern extent of the species' range. Unfortunately, systematic reporting of encounters with sunflower sea stars does not occur at this time.

The collection, drying, and trade of small "sunflower stars" is noted in Gravem *et al.* (2021) and in the ESA-listing petition received from the Center for Biological Diversity. This practice predominantly affects small stars under 15.25 cm in diameter and the retailers that offer these curios often do not list the species, site of collection, or other details necessary to determine whether populations of sunflower sea star are being directly impacted. Given that sea stars can be collected in Alaska, British Columbia, and Mexico, and in California seaward of a tidal exclusion zone, a more thorough evaluation of retail offerings is needed. Without additional information, the SRT unanimously decided that this threat has an unknown, but likely negligible, impact on extinction risk in the foreseeable future due to a lack of demand and no evidence of a substantial market.

Disease or Predation

Disease, specifically SSWS, was identified by the SRT as the single greatest threat affecting the persistence of the sunflower sea star both now and into the foreseeable future (Lowry *et al.* 2022). While the etiology of the disease as well as what trigger(s) resulted in its rapid spread to pandemic levels remain unknown (Hewson *et al.* 2018), the widespread occurrence of, and impacts from, the disease from 2013 through 2017 are broadly documented. Initially, SSWS was thought to be caused by one, or a suite, of densoviruses (Paraviridae; Hewson *et al.* 2014; 2018); however, subsequent studies determined that the disease is more complex. A number of factors ranging from environmental stressors to the microbiome in the sea stars may play a role (Lloyd and Pespeni 2018; Konar *et al.* 2019; Aquino *et al.* 2021). Ocean warming has also been linked to outbreaks, hastening disease progression and severity (Harvell *et al.* 2019; Aalto *et al.* 2020). Regardless of the pathogen's unknown etiology to date, stress and rapid degeneration ultimately result with symptomatic sea stars suffering from abnormally twisted arms, white lesions, loss of body tissue, arm loss, disintegration, and death. During the 2013–2017 pandemic, populations of sunflower sea stars were diminished range wide, and in southern portions of the range estimated losses are on the order of 95 percent or more. There was considerable variation in the degree of impact associated with depth, latitude, and (sometimes) recent temperature regime, but projected losses in all regions where data were sufficient amounted to approximately 90 percent or more (Gravem *et al.* 2021). Lowry *et al.* (2022) demonstrate that these declines have continued at least through 2021 in most regions, though recent settlement events have been recorded in the Salish Sea and Alaska. Whether new cohorts will survive long enough to reproduce, or succumb to SSWS, is highly uncertain. Whether reproductive adults that survived the SSWS pandemic will demonstrate resistance or immunity to future outbreaks is also crucial to whether the species will survive. If impacts from SSWS continue at a level that resulted in population declines of greater than 90 percent over a 5-year timespan, extinction risk would be very high for the sunflower sea star. If population growth rates are able to return to pre-pandemic levels in coming years, the likelihood of population persistence is moderate in the Alaska Region and the British Columbia and Salish Sea Region, but lower in the West Coast Region from Washington to Mexico (Lowry *et al.* 2022).

There is no evidence that other known diseases constitute substantial threats to the continued persistence of the sunflower sea star now or in the foreseeable future. However, the SRT noted that a complicating factor is that the physiological response of sea stars to numerous stressors (*e.g.*, high temperature, low dissolved oxygen) is to develop lesions, autotomize arms, and/or disintegrate (Lowry *et al.* 2022). These symptoms, and the ultimate outcome of disintegration, are shared with SSWS, making it possible that a suite of disease pathogens or stressors jointly contribute to the observed syndrome. As the end result of any such disease is mortality within just a few days, the threat from disease still remains high whether SSWS is caused by a single pathogen or many.

Very few predators are known to consume adult sunflower sea stars and this is not expected to change even under generous projections of ecosystem changes as a consequence of global climate change or other factors. Predation risk is likely highest during the planktonic larval phase when indiscriminate filter feeders consume small larvae and selective pickers target larger, more developed individuals. The prolonged duration of the larval period could enhance this risk, but there is no evidence to suggest that current risks of predation are any higher than they were prior to the pandemic when populations were healthy. Additionally, while the fecundity of the sunflower sea star is not well known, even conservative estimates suggest that an individual female likely produces millions of eggs in a single spawning event. As such, the SRT determined that predation is not likely to substantially contribute to extinction risk, now or in the foreseeable future (Lowry *et al.* 2022).

Inadequacy of Existing Regulatory Mechanisms

As noted above, in Washington and Oregon harvest and collection of sunflower sea stars are not allowed, but in Alaska, British Columbia, California, and Mexico recreational harvest is permitted. Though data are not available to determine how intensive this harvest is, human consumption is not known to occur and large markets for dried or otherwise processed specimens do not exist. Considering this information, the SRT determined that the current harvest and collection regulations do not contribute substantially to extinction risk, nor are they likely to in the foreseeable future (Lowry *et al.* 2022). Inconsistency of regulations across jurisdictions could complicate enforcement, however, unless coordinated efforts to standardize or reconcile rules occur. It may also become necessary in the foreseeable future to propose and publicize handling recommendations for bycaught sunflower sea stars to reduce handling stress and mortality, should data support that this is a more significant threat than currently recognized. Draft handling recommendations are currently under development within NOAA Fisheries for use in scientific surveys and will be adapted, as needed, for fisheries.

A patchwork of place-based conservation measures exists across the known range of the sunflower sea star that are designed to protect ecologically sensitive and/or important habitats and species. While none of these are specifically directed at conservation of the sunflower sea star or its habitat, many of them provide indirect protection to the species, its habitat, and its prey.

Current regulations to control anthropogenic climate change are likely insufficient to have a measurable impact on trends in changing ocean conditions, and resulting ecological effects, by the end of the century (Frölicher and Joos, 2010; Ahmadi Dehrashid *et al.* 2022). The effectiveness of regulations controlling anthropogenic climate change is a considerable concern because such regulations affect stressors like elevated sea surface temperature and lowered pH, which have sweeping effects on marine prey base and living conditions (Doney *et al.* 2012). Elevated ocean temperatures likely contributed to the decline of the sunflower sea star because warmer water temperatures are correlated with accelerated rates of SSWS transmission and disease-induced mortality; therefore the lack of adequate regulations to stall the impacts of climate change also presents a direct concern for the long-term viability of the sunflower sea star. There is uncertainty regarding ways in which additional climate change regulations could affect the extinction risk of the sunflower sea star without a better understanding of the relationships between climate change impacts (especially temperature stress), SSWS dynamics, and species-specific disease vulnerability.

The SRT identified considerable uncertainty regarding what regulatory mechanisms might effectively reduce extinction risk as a consequence of SSWS (Lowry *et al.* 2022). While a given disease can sometimes be isolated to a geographic region or eliminated by a combination of quarantine, transport embargos of specimens carrying the pathogen, or the administration of vaccines, these actions all require considerable knowledge of the disease itself. In the case of SSWS, the pathogen has not yet been identified, the cause may be several pathogens with similar etiologies, and the disease has been observed across the full geographic range of the species. For these reasons, while existing regulatory mechanisms are insufficient to address the threat of SSWS, the SRT determined that it is unlikely that any effective regulatory approaches will arise in the foreseeable future without considerable research (Lowry *et al.* 2022).

Other Natural or Man-Made Factors Affecting Its Continued Existence

Direct impacts of environmental pollutants to the sunflower sea star are unknown, but they likely have similar effects to those seen in other marine species, given physiologically similar processes. Reductions in individual health and disruption of nutrient cycling through food webs are hallmarks of industrial chemicals, heavy metals, and other anthropogenic contaminants. With the sunflower sea star representing a monotypic genus, the SRT noted substantial uncertainty involved with projecting potential impacts into the foreseeable future, and decided that extrapolating effects of specific chemicals or suites of chemicals to range-wide population viability is impossible (Lowry *et al.* 2022). Any impacts that do exist are likely to be more intensive near their source, such as urban bays and estuaries, though many persistent contaminants are known to bioaccumulate in some organisms and spread over long distances over the course of decades or more.

The addition of anthropogenically released greenhouse gasses into the atmosphere since the industrial revolution has resulted in climate change that is affecting organisms and environments on a global basis. While direct linkages between climate change and sunflower sea star population status have not been made in the literature, impacts to prey base, habitat, and SSWS can all be inferred from available data. Ecosystem change rooted in climate forcers has already been demonstrated in nearshore ecosystems of the north Pacific Ocean (*e.g.,* Bonaviri *et al.* 2017; Berry *et al.* 2021), resulting in prey base instability that adds additional stress to struggling populations. See above for a discussion of how climate change may link to progression and severity of SSWS outbreak as a consequence of changes in sea surface temperature and physiochemical properties of marine waters.

Larval life stages of numerous shell-forming marine organisms are highly sensitive to chemical composition of pelagic waters, such that ocean acidification can increase physiological stress and decrease survival in a broad array of organisms. Additionally, life stages of various planktonic organisms are sensitive to temperature, with elevated temperature increasing metabolic rate and, thus, nutritional requirements. Furthermore, some marine organisms rely on seasonal shifts in temperature and other environmental cues to identify suitable spawning times, aligning planktonic feeding periods of larvae with phytoplankton blooms. Changes in the spatiotemporal availability and quality of prey affect planktotrophic larvae and may result in reduced growth, delayed settlement, starvation, and various other negative outcomes. Though the planktonic diet of sunflower sea star larvae has not been adequately described, it is likely that they consume shell-forming organisms to various degrees depending on spatiotemporal variability in abundance, quality, and encounter rate. Nearshore benthic communities can also be affected in myriad ways by elevated carbon dioxide levels, reduced pH, increased temperature, and other physiochemical changes resulting from anthropogenic climate change. While these effects of climate change are unlikely to affect the sunflower sea star across its full range simultaneously, the SRT noted that decreases in habitat suitability are likely on a localized basis and such stressors could exacerbate consequences of low abundance, especially in southern portions of the range (Lowry *et al.* 2022). High levels of uncertainty regarding complex interactions among climate-related stressors and their impacts on sunflower sea star population viability, however, make it impossible to adequately project effects on extinction risk into the foreseeable future.

Overall Extinction Risk Summary

Throughout the Range of the Species

Little is known about several fundamental biological aspects of the sunflower sea star, such as age at maturity, longevity, growth rate, reproductive output, population resiliency, and population connectivity. What is known is that the species is a broadcast spawner, utilizes a broad range of habitats and prey, and has a broad geographic distribution, all of which buffer the species against catastrophic events and reduce overall extinction risk. The abundance and density of the species have clearly declined recently throughout the vast majority of its range; however, data are highly uncertain in deep waters and less accessible/well surveyed regions. Additionally, most current SCUBA- and trawl-based protocols fail to sample small individuals (*e.g.,* those less than 5 cm as measured from arm-tip to arm-tip), making characterization of population status incomplete. In some areas, functional extirpation is likely within the foreseeable future of 30 years due to a lack of mate availability, which constrains reproductive capacity and limits settlement of new cohorts. Best available estimates indicate that the remaining range-wide abundance of the sunflower sea star is approximately 600 million individuals, with the highest abundances in Alaska and British Columbia, primarily in deeper water (at lower densities than observed in shallow, scuba-accessible depths).

Given the widespread impacts of SSWS from 2013 through 2017, it is likely that surviving sunflower sea stars were exposed, giving hope (but no direct evidence) that they bear some resistance to the causative agent of the disease, though this agent remains unknown. SSWS is the single greatest threat to the sunflower sea star on a range-wide basis, and may be exacerbated by global warming, ocean acidification, toxic contaminants, and other processes that generate physiological stress in individuals. A conclusive link has not been demonstrated but is likely given physiology and known stressors of this, and other, sea star species. Regions most likely to be impacted by climate change factors are in the south, where the sunflower sea star population was most heavily impacted by the SSWS pandemic. Fishing pressure (including bycatch), the curio trade, and habitat degradation are threats, but are not anticipated to have population-level impacts in the next 30 years. Regional variability in threat severity could result in total loss of the species in the southern portion of its geographic range, but whether the loss of this portion of the population may compromise the long-term viability of the species is unknown. Overall, threats to population persistence exist, with high uncertainty about potential impacts, and with trajectories in many areas continuing downward. As a result of this analysis of aspects of species viability and threats facing the species, we conclude that the sunflower sea star is at moderate risk of extinction now and in the foreseeable future throughout its range.

Significant Portion of Its Range

Under the ESA, a species may warrant listing if it is in danger of extinction now or in the foreseeable future throughout all or a significant portion of its range. Having concluded that the sunflower sea star is at moderate risk of extinction now and in the foreseeable future throughout all of its range, the SRT next conducted an assessment to determine whether it may currently be in danger of extinction in any identified significant portion of its range (SPR). If a species is in danger of extinction in an SPR, the species qualifies for listing as an endangered species (79 FR 37578; July 1, 2014). In 2014, the USFWS and NMFS issued a joint policy on interpretation of the phrase "significant portion of its range" (SPR Policy, 79 FR 37578; July 1, 2014). The SPR Policy set out a biologically-based approach for interpreting this phrase that examines the contributions of the members of the species in the "portion" to the conservation and viability of the species as a whole. More specifically, the SPR Policy established a threshold for determining whether a portion is "significant" that involved considering whether the hypothetical loss of the members in the portion would cause the overall species to become threatened or endangered. This threshold definition of "significant" was subsequently invalidated in two District Court cases, which held that it set too high a standard to allow for an independent basis for listing species—*i.e.* it did not give independent meaning to the phrase "throughout . . . a significant portion of its range" (*Center for Biological Diversity, et al.* v. *Jewell, 248 F. Supp. 3d 946, 958 (D. Ariz. 2017); Desert Survivors* v. *DOI 321 F. Supp. 3d. 1011 (N.D. Cal., 2018).* However, those courts did not take issue with the fundamental approach of evaluating significance in terms of the biological significance of a particular portion of the range to the overall species. While the SRT did not rely on the definition of "significant" in the policy when conducting their analysis, they did use a biological approach to assessing whether any portions of the sea star's range are "significant."

To identify potential SPRs for the sunflower sea star, the SRT considered the following: (1) is there one or more population segment at higher risk of extinction relative to population segments elsewhere in the range; and (2) is the higher-risk population segment biologically significant to the overall viability of the species. To analyze whether a portion qualifies as significant the SRT considered the viability characteristics of abundance, productivity, spatial distribution, and genetic diversity. Ultimately, the goal of this analysis was to determine whether the sunflower sea star is in danger of extinction in a significant portion of its range.

To help in identifying potential SPRs, SRT members were provided a base map of the northeast Pacific Ocean labeled with several geophysical features either referenced in the IUCN status assessment of the sunflower sea star (Gravem *et al.* 2021) or known to be associated with demographic breaks in a variety of other marine organisms. Team members independently considered all data and information available on a regional basis to generate proposed areas that could potentially represent SPRs, that is, areas that have a reasonable likelihood of being at high risk of extinction and that have a reasonable likelihood of being biologically significant to the species. These portions were highlighted on the map, and detailed justifications provided regarding the intensity of specific threats to, and biological significance of, the population segment in the identified portion(s). Because there are theoretically an infinite number of ways in which a species' range may be divided for purposed of an SPR analysis, only those portions that the SRT identified as ones where the species has a reasonable likelihood of being both at higher risk of extinction relative to the rest of the range and biologically significant to the overall species were considered further in the analysis.

After considering all available biological, geographic, and flow regime data available; evaluating issues of data resolution, representativeness, and availability; and drawing on proxy species where necessary, the SRT delineated three portions in which trends in biological viability, threat intensity, and likely biological significance were internally consistent. These were: (1) all waters of the range north of Dixon Entrance (*i.e.,* waters of Alaska; Portion 1); (2) coastal British Columbia and the Salish Sea (Portion 2); and (3) all waters of the range south of Cape Flattery, to Baja California, Mexico (Portion 3). In waters shallower than 25 m, where assessment data are most readily available and comprehensive (Gravem *et al.* 2021; Lowry *et al.* 2022), over 72 percent of the pre-pandemic abundance of sunflower sea stars occupied Portion 1. Portion 2 is estimated to have held approximately 17.5 percent of the population. Despite being geographically extensive, Portion 3 was estimated to be occupied by the remainder of the species, just under 10 percent of the total shallow-water population. It is worth noting that nearly 45 percent of the pre-pandemic population was estimated to occupy waters deeper than 25 m, which are disproportionately located off of Alaska and coastal British Columbia, further amplifying these patterns. Taken together, the SRT determined that these estimates indicate the existence of a population center in the North Pacific, a transition zone along coastal British Columbia and into the Salish Sea, and a southward extension of the species through temperate waters at limited abundance/density until thinning out in the subtropics around the Southern California Bight.

The population center of the sunflower sea star is in Alaskan waters, and the population segment here was less impacted by SSWS with considerably more individuals surviving (over 275 million in shallow waters and as many as 400 million in deep waters [Gravem *et al.* 2021]) and no apparent reduction in spatial distribution. Given this, the SRT determined that the population segment occupying Portion 1 is not at higher risk of extinction than the species overall. Because the status of the species in Portion 1 does not differ from the status throughout the range, the SRT did not continue the analysis further to determine whether Portion 1 constitutes a significant portion of the species' range.

Conversely, waters of Portion 3 are estimated to have held less than ten percent of the pre-pandemic population of species and saw losses >95 percent from 2013 to 2017, with few signs of recovery. While it is possible individuals in this portion that survived the pandemic are disease resistant, or contain genes for thermal tolerance or adaptability to other environmental parameters, data do not exist at this time to support this assertion. Furthermore, being at the southern end of a current system that flows predominantly southward it is unlikely that these traits could be naturally transmitted into northern populations via planktonic drift. Taken together, this caused the SRT to conclude that while risk of extinction may be higher in the southern portion of the range due to dramatically decreased abundance, density, and frequency of occurrence post pandemic, this population segment is not likely to be biologically significant relative to the overall viability of the species. As such, Portion 3 does not constitute a significant portion of the range for ESA status assessment purposes.

Portion 2 is situated where currents flow both north and south into other portions of the range, uniquely positioning it to serve as a biologically significant population with regard to long-term persistence of the sunflower sea star. Higher abundance within the region may allow the population here to contribute to population viability in Southeast Alaska, the Washington coast, and beyond. In addition, while there is recruitment to offshore sites, and relatively healthy populations in some glacial fjords, there is evidence of source/sink dynamics (*i.e.*, areas of high reproductive capacity within the region produce larvae that settle elsewhere in the region) within Portion 2. The possibility of disease resistance in these remaining individuals cannot be discounted, but has not been demonstrated. Persistent low encounter rates in the region, however, suggest a degree of resiliency despite ongoing occurrence of the causative agent of the disease (whatever it may be) in the environment. The Salish Sea region is influenced by a number of other threats, such as toxic contamination, pressure from a diversity of fisheries, and extensive habitat degradation and destruction associated with creation and maintenance of human infrastructure. To assess whether these threats elevated overall extinction risk to high in the biologically significant Portion 2, a second overall extinction risk scoring sheet was distributed and team members independently assessed this region. Though there is a high degree of uncertainty with regard to the potential impact of SSWS and other threats on the population segment in this portion, the SRT determined that overall extinction risk in Portion 2 is moderate, matching that of the range-wide assessment and thereby precluding assignment of high extinction risk to the species based on status within this particular portion of its range.

Given the best available information, we find that the sunflower sea star is at a moderate risk of extinction throughout its range, as well as within Portion 2 (the British Columbia Coast and Salish Sea), the only portion of the range determined to be biologically significant. Without efforts to better understand the etiology of SSWS and identify paths to address its impacts on the sunflower sea star, the species is on a trajectory in which its overall abundance will likely significantly decline within the foreseeable future, eventually reaching the point where the species' continued persistence will be in jeopardy. These declines are likely to be exacerbated by anthropogenic climate change and the resulting impacts on biogeochemical aspects of habitats occupied by the species. Although the species is not currently in danger of extinction throughout its range, it will likely become an endangered species within the foreseeable future.

Protective Efforts

Having found that the sunflower sea star is likely to become in danger of extinction throughout its range within the foreseeable future, we next considered protective efforts as required under section 4(b)(1)(A) of the ESA. The focus of this evaluation is to determine whether protective efforts are being made and, if so, whether they are effective in ameliorating the threats we have identified to the species and thus, potentially, avert the need for listing. As we already considered the adequacy of existing regulatory efforts associated with fisheries and place-based ecosystem protections in our evaluation of threats above, we consider other conservation efforts in this section.

Following the 2020 IUCN assessment of the sunflower sea star (Gravem *et al.* 2021), the species was conferred Critically Endangered status on the Red List of Threatened Species (*https://www.iucnredlist.org/species/178290276/197818455*). Subsequent to this, The Nature Conservancy convened a working group made up of state, tribal, Federal, and provincial government; academic; and non-profit partners to create a roadmap to recovery for the species. This document uses the best available science and information to identify specific, targeted research and management efforts needed to address what workgroup participants identify as the greatest threats facing long-term persistence of the sunflower sea star (Heady *et al.* 2022). Many contributors to this document provided data and knowledge to the SRT to ensure all of the most recent research was captured in our analysis (Lowry *et al.* 2022). The roadmap also includes an inventory of knowledge gaps that can be used as a guidance tool by partner organizations to coordinate collaborative research and management directed at sunflower sea star recovery (Heady *et al.* 2022), in many ways paralleling the structure and intent of a formal recovery plan under the ESA.

While we find that protective efforts associated with the roadmap to recovery will help increase public and scientific knowledge about the sunflower sea star and SSWS, and will likely result in multinational coordination on both research and management, such actions alone do not significantly alter the extinction risk for the sunflower sea star to the point where it would not be in danger of extinction in the foreseeable future. We seek additional information on these and other conservation efforts in our public comment process (see *Public Comments Solicited on Proposed Listing* below).

Determination

Section 4(b)(1)(A) of the ESA requires that listing determinations are based solely on the best scientific and commercial information and data available after conducting a review of the status of the species and taking into account those efforts, if any, being made by any state or foreign nation, or political subdivisions thereof, to protect and conserve the species. We have independently reviewed the best available scientific and commercial information including the petition, public comments submitted on the 90-day finding (86 FR 73230; December 27, 2021), the status review report (Lowry *et al.* 2022), and other published and unpublished information, and have consulted with species experts and individuals familiar with the sunflower sea star.

As summarized above, and in Lowry *et al.* (2022), we assessed the ESA section 4(a)(1) factors both individually and collectively for the sunflower sea star, throughout its range and in portions of its range, and conclude that the species faces ongoing threats from SSWS and direct (*i.e.*, physiological) and indirect (*i.e.*, ecological) consequences of anthropogenic climate change. Over 90 percent of the abundance of the species was lost over the period from 2013 to 2017, there are few positive signs of recovery, and we do not yet know the etiology of SSWS. Likely linkages of SSWS with environmental parameters that are projected to worsen with ongoing climate change suggest that impacts on the species from SSWS will likely persist and potentially worsen over the foreseeable future throughout the range.

We found no evidence of protective efforts for the conservation of the sunflower sea star that would eliminate or adequately reduce threats to the species to the point where it would not necessitate listing under the ESA. Therefore, we conclude that the sunflower sea star is likely to become an endangered species in the foreseeable future throughout its range from threats of disease and anthropogenic climate change. As such, we have determined that the sunflower sea star meets the definition of a threatened species and propose to list it is as such throughout its range under the ESA.

Effects of Listing

Measures provided for species of fish or wildlife listed as endangered or threatened under the ESA include: development of recovery plans (16 U.S.C. 1533(f)); designation of critical habitat, to the maximum extent prudent and determinable (16 U.S.C. 1533(a)(3)(A)); and the requirement for Federal agencies to consult with NMFS under section 7 of the ESA to ensure the actions they fund, conduct, and authorize are not likely to jeopardize the continued existence of the species or result in adverse modification or destruction of any designated critical habitat (16 U.S.C. 1536(a)(2)). Certain prohibitions, including prohibitions against "taking" and importing, apply with respect to endangered species under section 9 (16 U.S.C. 1538), and, at the discretion of the Secretary, some or all of these prohibitions may be applied to threatened species under the authority of section 4(d) (16 U.S.C. 1533(d)). Other benefits to species from ESA listing include recognition of the species' status and threats, which can promote voluntary conservation actions by Federal and state agencies, foreign entities, private groups, and individuals.

Identifying Section 7 Conference and Consultation Requirements

Section 7(a)(4) of the ESA and implementing regulations require Federal agencies to confer with us on actions likely to jeopardize the continued existence of species proposed for listing, or that result in the destruction or adverse modification of proposed critical habitat. If a proposed species is ultimately listed, Federal agencies must consult under section 7(a)(2) on any action they authorize, fund, or carry out if those actions may affect the listed species or its critical habitat to ensure that such actions are not likely to jeopardize the species or result in destruction or adverse modification of critical habitat should it be designated. At this time, based on the currently available data and information, we determine that examples of Federal actions that may affect the sunflower sea star include, but are not limited to: discharge of pollution from point and non-point sources, contaminated waste disposal, dredging, marine cable laying, pile-driving, development of nearshore infrastructure, development of water quality standards, military activities, and fisheries management practices. None of the actions on this list were scored as moderate or high risk to the sunflower sea stars or identified as a significant cause of their recent population decline. Their effects, even if small, would be subject to section 7 consultations if the sea star sunflower is listed as threatened. For example, Federal fisheries were identified as low risk, and for specific fisheries that employ bottom contact gear and have known or presumed bycatch, we would anticipate evaluating the relatively low risk, then focusing on measures to minimize or better understand effects, such as species identification and reporting by fishery observers and development of safe handling practices.

Critical Habitat

Critical habitat is defined in the ESA (16 U.S.C. 1532(5)(A)) as: (1) the specific areas within the geographical area occupied by a species, at the time it is listed in accordance with the ESA, on which are found those physical or biological features (a) essential to the conservation of the species and (b) which may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by a species at the time it is listed upon a determination that such areas are essential for the conservation of the species. "Conservation" means the use of all methods and procedures needed to bring the species to the point at which listing under the ESA is no longer necessary. Section 4(a)(3)(A) of the ESA requires that, to the maximum extent prudent and determinable, critical habitat be designated concurrently with the listing of a species. Designations of critical habitat must be based on the best scientific data available and must take into consideration the economic, national security, and other relevant impacts of specifying any particular area as critical habitat. When developing critical habitat designations we often seek data and public comment on these aspects such as: (1) maps and specific information describing the amount, distribution, and use type (*e.g.*, spawning) of the habitat, as well as any additional information on occupied and unoccupied habitat areas; (2) the reasons why any specific area of habitat should or should not be determined to be critical habitat as provided by sections 3(5)(A) and 4(b)(2) of the ESA; (3) information regarding the benefits of designating particular areas as critical habitat; (4) current or planned activities in the areas that might qualify for designation and their possible impacts;

(5) any foreseeable economic or other potential impacts resulting from designation, and, in particular, any impacts on small entities; (6) whether specific unoccupied areas may be essential for the conservation of the species; and (7) individuals who could serve as peer reviewers in connection with a proposed critical habitat designation, including persons with biological and economic expertise relevant to the species, region, and designation of critical habitat.

As part of the status review process (Lowry *et al.* 2022) and proposed threatened listing we have conducted an exhaustive review of available information on many of the above elements, particularly related to distribution, habitat use, and biological features. Sunflower sea stars are habitat generalists, occurring on a wide array of abiotic and biotic substrates over a broad depth range. Few systematic surveys have been conducted to differentiate habitat use, such as spawning/rearing, or identify features across different depths, latitudes, substrates, temperatures, or other potentially important biological parameters. At this time, we find that critical habitat for the sunflower sea star is not determinable because data sufficient to perform the required analyses are lacking. Specifically, we do not have sufficient information regarding physical and biological habitat features associated with sunflower sea star occurrence that may be essential to their conservation.

We therefore seek public input on physical and biological habitat features and areas that are essential to the conservation of the sunflower sea star in U.S. waters. If we determine that designation of critical habitat is prudent and determinable in the future, we will publish a proposed designation of critical habitat for the sunflower sea star in a separate rule.

Protective Regulations Under Section 4(d) of the ESA

In the case of threatened species, ESA section 4(d) gives the Secretary discretion to determine whether, and to what extent, to extend the prohibitions of section 9 to the species, and authorizes the issuance of regulations necessary and advisable for the conservation of the species. Thus, we have flexibility under section 4(d) to tailor protective regulations, taking into account the effectiveness of available conservation measures. The 4(d) protective regulations may prohibit, with respect to threatened species, some or all of the acts which section 9(a) of the ESA prohibits with respect to endangered species. We are not proposing such regulations at this time, given the minimal impacts of habitat degradation/destruction, fisheries, trade, and manmade factors (other than climate change described above), but we may consider potential protective regulations pursuant to section 4(d) for the sunflower sea star in a future rulemaking. For example, the impacts of the specific threats that could potentially be addressed through a 4(d) rule, such as pollution, collection/trade, or fisheries, were all identified as low risk. Therefore, at this time we conclude that management under 4(d) would be unlikely to provide meaningful protection. In order to inform our consideration of appropriate protective regulations for the species in the future if our understanding of threats evolves, we are seeking information from the public on threats to the sunflower sea star and possible measures for its conservation.

Role of Peer Review

The intent of peer review is to ensure that listings are based on the best scientific and commercial data available. In December 2004, OMB issued a Final Information Quality Bulletin for Peer Review establishing minimum peer review standards, a transparent process for public disclosure of peer review planning, and opportunities for public participation. The OMB Bulletin, implemented under the Information Quality Act (Pub. L. 106–554), is intended to enhance the quality and credibility of the Federal Government's scientific information, and applies to influential or highly influential scientific information disseminated on or after June 16, 2005. To satisfy our requirements under the OMB Bulletin, we are obtaining independent peer review of the status review report concurrent with the public comment period associated with this proposed rule. All comments will be considered and addressed prior to publication of the final rule in which we make the decision whether to list the sunflower sea star.

Public Comments Solicited on Proposed Listing

To ensure that the final action resulting from this proposal will be as accurate and effective as possible, we solicit comments and suggestions from the public, other governmental agencies, the scientific community, industry, tribal entities, environmental groups, and any other interested parties. Comments are encouraged on all aspects of this proposal (See **DATES** and **ADDRESSES**). We are particularly interested in: (1) new or updated information regarding the range, distribution, and abundance of the sunflower sea star; (2) new or updated information regarding the genetics and population structure of the sunflower sea star; (3) new or updated information regarding past or current habitat occupancy by the sunflower sea star; (4) new or updated biological or other relevant data concerning any threats to the sunflower sea star (*e.g.,* landings of the species, illegal taking of the species); (5) information on commercial trade or curio collection of the sunflower sea star; (6) recent observations or sampling of the sunflower sea star; (7) current or planned activities within the range of the sunflower sea star and their possible impact on the species; and (8) efforts being made to protect the sunflower sea star.

Public Comments Solicited on Critical Habitat

As noted above, we have concluded that critical habitat is not currently determinable for the sunflower sea star. We request information that would contribute to consideration of critical habitat in the future, such as new data describing the quality and extent of habitat for the sunflower sea star, information on what might constitute physical and biological habitat features and areas that are essential to the conservation of the species, whether such features may require special management considerations or protection, or identification of areas outside the occupied geographical area that may be essential to the conservation of the species and that are under U.S. jurisdiction.

In addition, as part of any potential critical habitat designation we may propose, we would also need to consider the economic impact, impact on national security, and any other relevant impact of designating any particular area as critical habitat as required under section 4(b)(2) of the ESA. Therefore, we are also soliciting information to inform these types of analyses, including information regarding: (1) activities or other threats to the essential features of occupied habitat or activities that could be affected by designating a particular area as critical habitat; and (2) the positive and negative economic, national security, and other relevant impacts, including benefits to the recovery of the species, likely to result if particular areas are designated as critical habitat.

References

A complete list of the references used in this proposed rule is available at *https://www.fisheries.noaa.gov/species/sunflower-sea-star* and upon request (see **ADDRESSES**).

Classification

National Environmental Policy Act

The 1982 amendments to the ESA, in section 4(b)(1)(A), restrict the information that may be considered when assessing species for listing. Based on this limitation of criteria for a listing decision and the opinion in *Pacific Legal Foundation* v. *Andrus*, 657 F. 2d 829 (6th Cir. 1981), NMFS has concluded that ESA listing actions are not subject to the environmental assessment requirements of the National Environmental Policy Act (NEPA).

Executive Order 12866, Regulatory Flexibility Act, and Paperwork Reduction Act

As noted in the Conference Report on the 1982 amendments to the ESA, economic impacts cannot be considered when assessing the status of a species. Therefore, the economic analysis requirements of the Regulatory Flexibility Act are not applicable to the listing process. In addition, this proposed rule is exempt from review under Executive Order 12866. This proposed rule does not contain a collection-of-information requirement for the purposes of the Paperwork Reduction Act.

Executive Order 13132, Federalism

Executive Order 13132 requires agencies to take into account any federalism impacts of regulations under development. It includes specific directives for consultation in situations where a regulation will preempt state law or impose substantial direct compliance costs on state and local governments (unless required by statute). Neither of those circumstances is applicable to this action.

List of Subjects in 50 CFR Part 223

Endangered and threatened species.

Dated: March 10, 2023.

Samuel D. Rauch, III,

Deputy Assistant Administrator for Regulatory Programs, National Marine Fisheries Service.

For the reasons set out in the preamble, NOAA proposes to amend 50 CFR part 223 as follows:

PART 223—THREATENED MARINE AND ANADROMOUS SPECIES

■ 1. The authority citation for part 223 continues to read as follows:

Authority: 16 U.S.C. 1531–1543; subpart B, § 223.201–202 also issued under 16 U.S.C. 1361 *et seq.*; 16 U.S.C. 5503(d) for § 223.206(d)(9).

■ 2. Amend § 223.102, in paragraph (e), by adding a new table subheading for "Echinoderms" before the "Molluscs" subheading, and adding a new entry for "Sunflower Sea Star" under the "Echinoderms" table subheading to read as follows:

§ 223.102 Enumeration of threatened marine and anadromous species.

* * * * *

(e) * * *

Species[1]			Citation(s) for listing determination(s)	Critical habitat	ESA rules
Common name	Scientific name	Description of listed entity			
*	*	*	*	*	*
			Echinoderms		
Sunflower Sea Star.	*Pycnopodia helianthoides.*	Entire species ...	*[Insert* **Federal Register** *citation and date when published as a final rule].*	NA	NA.
*	*	*	*	*	*

[1] Species includes taxonomic species, subspecies, distinct population segments (DPSs) (for a policy statement, see 61 FR 4722, February 7, 1996), and evolutionarily significant units (ESUs) (for a policy statement, see 56 FR 58612, November 20, 1991).

[FR Doc. 2023–05340 Filed 3–15–23; 8:45 am]

BILLING CODE 3510–22–P