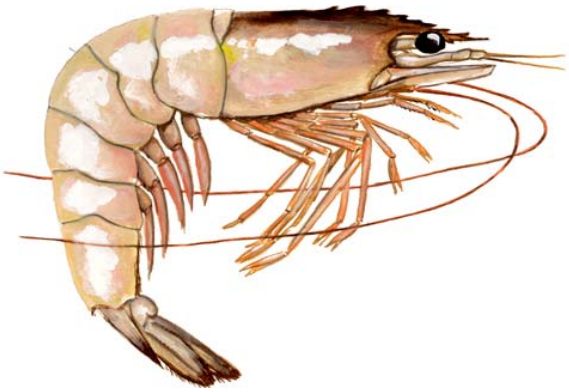
Seafood Watch
Seafood Report

MONTEREY BAY AQUARIUM®

Wild-Caught Warmwater Shrimp
(Family Penaeidae--the Penaeid shrimps)



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Final Report
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About Seafood Watch® and the Seafood Reports

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from the Internet (seafoodwatch.org) or obtained from the Seafood Watch® program by emailing seafoodwatch@mbayaq.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices", "Good Alternatives" or "Avoid." The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Fisheries Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch's sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling 1-877-229-9990.

Disclaimer

Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Seafood Watch® and Seafood Reports are made possible through a grant from the David and Lucile Packard Foundation.

Introduction to Series on Shrimps:

This is Volume II in a series of three Seafood Reports covering the shrimps most frequently found in West Coast markets and restaurants.

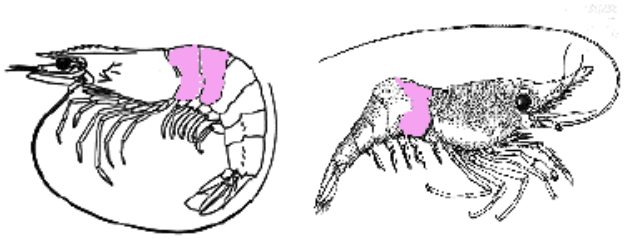
Volume Index:

General Shrimp Biology
Shrimps belong to the order Decapoda, a crustacean order which also includes the lobsters, true crabs, and hermit crabs. All decapods possess a full carapace or "head shield", and, eponomously, five pairs of walking legs [1]. Their first three pairs of thoracic appendages are modified into "maxillipeds", or feeding legs [2].

Shrimps are distinguished from the other decapods by having the front-most section of the abdomen about the same size as the rest of the sections, and by having five pairs of abdominal appendages, or pleopods, adapted for swimming [1].

There are more than 3,000 living species of shrimp worldwide [2]. Many are tiny, or inhabit ecological niches unsuited to mass harvest [1]. Those harvested on a commercial basis share two characteristics: they are relatively large, ranging roughly from 2-10 cm. carapace length, and they school, shoal, migrate toward baited traps, or otherwise aggregate so that they are amenable to capture. Worldwide, about 40 species of shrimp meet these criteria and are harvested commercially [3]. About ten species have been raised in captivity; for some species, such as the Pacific white shrimp *Penaeus vannamei*, selective breeding is developing truly "domesticated" breeds of shrimp.

Scientific Names and Shrimp vs. Prawn
While there is no hard and fast rule about applying the names “shrimp” and “prawn” [Watling, 2004; Shumway, 2003], certain scientific references state that "shrimp" refers to the infraorder Caridea, which includes the widely-harvested coldwater genera *Pandalus* and *Crangon* [2]. With more than 2,000 species, these so-called “true shrimp” [2] are the largest group of shrimplike decapods [2]. They are distinguished by overlapping exoskeletal plates on their first, second, and third abdominal segments [2]. Under this definition, “prawn” refers to members of the family Penaeidae, which includes the penaeids or tropical shrimp [2]. Also known as the “primitive shrimp”, prawns are distinguished by the fact that their first and second anterior segments are about the same size [2].



A typical prawn A typical shrimp

Image after MuseumVictoria , Australia

However, there is vast confusion among the common names of these animals. The "spot prawn" *(Pandalus platyceros)* of the U.S. West Coast is in fact a shrimp [2], [3]; while in British usage only the genus *Palaemon*, with its prominent head spine or rostrum, can be called a prawn [1].

In U.S. markets, "shrimp" is the default name for all these animals. "Prawn" often refers to freshwater shrimp or large saltwater shrimp. The term "scampi" refers not to a species but to a cooking method: any large shrimp cooked in butter and garlic [4]. Commercially-harvested shrimp may be divided into three categories, based upon their habitat: coldwater or northern species; warmwater, tropical, or southern species; and freshwater species [4].

Overview of Market Information

The market for shrimp continues to expand, and farmed shrimp supply an ever-increasing share of that market. About three-quarters of world shrimp production is wild-caught; approximately 70% of wild-caught shrimp are warmwater shrimp and approximately 30% are coldwater shrimp. The remaining quarter of total production is farm-raised shrimp [5, 6]. With worldwide shrimp fisheries at or near their maximum sustainable yield, any growth in shrimp production must come from farm-raised shrimp. Many nations are turning to farm-raised shrimp as an attractive source of international trade revenue.

Executive Summary:

The warmwater or tropical shrimps (mostly importantly the genus *Penaeus*) supply about 80% of the world's wild-caught shrimp. These shrimps are short-lived and very prolific, making them inherently invulnerable to fishing pressure. Wherever these shrimps occur, they are exploited at or near their maximum sustainable yield. Most tropical shrimp fisheries are captured by bottom trawling, a method which take high levels of bycatch, including significant numbers of endangered and threatened sea turtles. While technological innovations such as the turtle-excluder device have reduced bycatch in recent years, not all fisheries use them. Warmwater shrimp trawl fisheries are subject to continuing concern about high levels of bycatch of fish, invertebrates, and endangered sea turtles. While the use of TEDs has decreased the accidental deaths of turtles in these shrimp fisheries, regulation of shrimp trawlers is in the hands of the national fisheries agency of each shrimping nation. Among the many nations that catch tropical shrimp, management measures and enforcement of catch quotas and TED requirements vary widely. In addition, several nations have gone before the World Trade Organization to challenge U.S. laws designed to ensure that all shrimp imported into the U.S. is caught using TEDs. And, unfortunately, even where TEDs are employed, bycatch of finfish and invertebrates remains high. Most tropical shrimps are caught by bottom trawling, a method which can have severe effects on seafloor habitat (depending upon the type of habitat trawled). As of the latest figures available in 2003, about 87% of the U.S. shrimp supply was imported. This includes farmed and wild, warm- and coldwater- shrimp, with no way for the consumer to distinguish between them. It is hoped that the advent of country-of-origin labelling (COOL) in autumn 2004 will help U.S. consumers discern the source of their shrimp.

Table of Sustainability Ranks

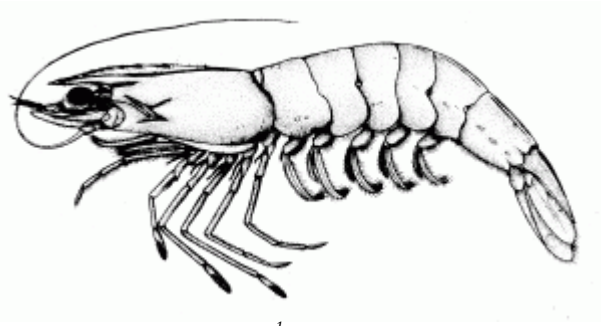
List of Five Component Ranks	Low Concern	Medium Concern	High Concern	Critical Concern
Inherent Vulnerability	√			
Status of Stocks	√			
Bycatch				√
Habitat Effects		√		
Management Effectiveness			√	

Trawl-caught warmwater shrimp, international sources **Overall Seafood Rank: Avoid**

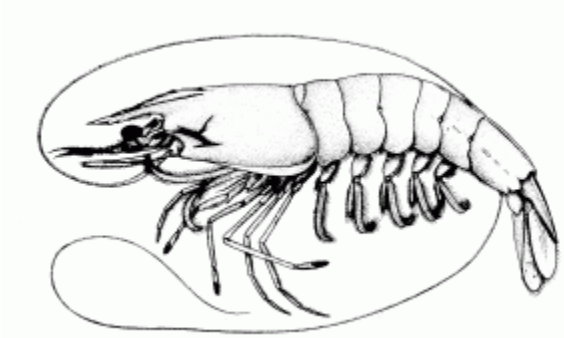
Seafood Watch is indebted to the outside experts who graciously volunteered their time to review the facts presented in this report for completeness and scientific accuracy: Dr. Todd Steiner, Sea Turtle Restoration Project; Dr. Les Watling, University of Maine. **It is important to note that scientific review does not constitute an endorsement of Seafood Watch® on the part of the reviewing scientists; the Seafood Watch® staff is solely responsible for the conclusions reached in this report.**

Warmwater Shrimps
(The Penaeids)

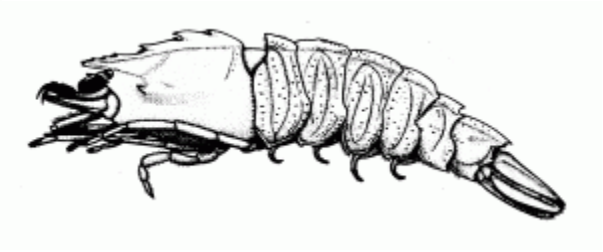
Penaeus chinensis, the Chinese white shrimp



Penaeus[1] *aztecus,* the Atlantic brown shrimp.



Penaeus[1] *setiferus,* the Atlantic white shrimp.



Siconia brevirostris, the Atlantic rock shrimp.

Images courtesy U.N. FAO FIGIS database

Introduction

Commercially-harvested shrimp may be divided into three categories, based upon their habitat: coldwater or northern species; warmwater, tropical, or southern species; and freshwater species [4]. While freshwater shrimp are important in aquaculture, they make up only a fraction of internationally-traded wild-caught shrimp. Most of the world's wild-caught shrimp fall into the coldwater and warmwater categories [4].

Warmwater or tropical shrimps account for approximately 80% of the world's wild-caught shrimp. The most valuable warmwater shrimp are members of the genus *Penaeus* (penaeid shrimps), which tend to be large and meaty. The international shrimp trade is largely based on these species [1], especially the Pacific white shrimp *(Penaeus*[1] *vannamei),* the brown shrimp *(P.*[1] *aztecus),* the Atlantic white shrimp *(P.*[1] *setiferus),* the pink penaeid shrimp *(P. duorarum)* [4] [8], the black tiger prawn *(Penaeus monodon)* and the Australian tiger prawns *(P. esculentes* and *P. semisculatus*) [9]. All of these are members of the infraorder Penaeidea, the prawns or "primitive shrimp". Subject to capture fisheries wherever they occur, several popular penaeids, notably *P. vannamei*, are also being farm-raised. Other warmwater shrimps captured in U.S. fisheries include the royal red shrimp *(Penaeus braziliensis),* a deepwater species; the seabob *(Xiphopenaeus*

[1] Some nomenclature systems designate New World penaeids as subgenus *Litopenaeus7. Perez Farfante, I.a.B.K., Penaeoid and Sergestoid Shrimps and Prawns of the World. Keys and Diagnoses for the Families and Genera. 1997, Paris, France: Memories du Museum National D'Historie Naturelle. 233.*

kroyeri); and the rock shrimps *(Sicyonia brevirostris* or *Penaeus megalops),* distinguished by their thick, hard shells [4] [8] [10].

Statement on the Availability of Science:
Warmwater shrimps are fished around the globe by many different nations. Fisheries information is most readily available from developed nations, such as the United States and Canada. However, even within these nations, different shrimp fisheries are administered by different regional bodies, some of which publish more than others. For many other nations, only shrimp landings data are readily available[15].

In recent years, a certain amount of research has been devoted to documenting levels of bycatch in warmwater shrimp fisheries. Bycatch of commercially-important fishes [16] and endangered sea turtles is of concern in many of these fisheries[15, 17]. International conservation organizations and several of the larger scientific journals have published general articles detailing the problem and highlighting potential solutions [6, 17, 18]. Research continues into bycatch-reducing modifications for shrimp fishing gear [6, 19].

Market Information:

Market Names:
It is important to note that the various species of shrimp are marketed interchangeably, traded not by species, but by *size*. It matters little to most restauranteurs whether their breaded shrimp is *Penaeus setiferus* or *Pandalus jordani*, as long as it's the right size. Thus, more perhaps than any other seafood commodity, the market names of shrimp are seldom standardized. Several different species are commonly called "white shrimp", and the situation is the same for "pink shrimp", "rock shrimp", and "tiger shrimp" [4]; [8]; [9]. Moreover, widely-distributed species have many common names. As one example, the circumpolar species *Pandalus borealis* may be marketed as pink shrimp, northern shrimp, northern pink shrimp, Pacific pink shrimp, or salad shrimp [20], [3]. Farmed and wild-caught shrimp enter the same markets and are traded interchangeably [5]. When used for sushi or sashimi, warmwater shrimp are commonly sold as *ebi*.

As of the latest figures available in 2003, about 87% of the U.S. shrimp supply was imported. This includes farmed and wild, warm- and coldwater- shrimp, with no way for the consumer to distinguish between them [Cutland & Cherry, 2002].

The following table lists the species names and common names for some of the United States' major market species of warmwater shrimps:

Scientific Name	Common Name	Habitat
warmwater shrimps		
Penaeus megalops	rock shrimp	warmwater Atlantic
Siconia brevirostris	rock shrimp	warmwater Atlantic
Penaeus braziliensis	red shrimp, royal red shrimp	warmwater Atlantic
Penaeus vannamei	white shrimp, Pacific white shrimp, Vanna White shrimp	warmwater Pacific
Penaeus setiferus	white shrimp, Atlantic white shrimp	warmwater Atlantic and Gulf of Mexico
Penaeus aztecus	brown shrimp	warmwater Atlantic and Gulf of Mexico

Penaeus duorarum	pink shrimp, pink penaeid shrimp	warmwater Atlantic and Gulf of Mexico
Penaeus monodon	black tiger prawn	southern Pacific
Penaeus esculentes	tiger prawn, Australian tiger prawn	southern Pacific
Penaeus semisculatus	tiger prawn, Australian tiger prawn	southern Pacific
Penaeus chinensis	white shrimp, Chinese white shrimp, fleshy prawn	Asia

Sources: [3, 9, 21] [4] [8]

The confusion of common names makes "creative marketing" a constant theme in shrimp sales. For instance, the Chinese white shrimp *Penaeus chinensis*, imported from China and Korea, sell on U.S. markets for far less than domestic white shrimp. But the species are similar enough that repacking of Chinese shrimp as domestic product often goes unnoticed [21]. Seafood marketers advise "*caveat emptor*"--let the buyer beware.

The Shrimp Count

Because shrimp are so small, they are sold by a count (number) per pound rather than by individual weight [21]. This is expressed as a range. For example, a 16/20 count means shrimp of such a size that it would take from 16 to 20 of them to make up a pound [21]. The rule is, “the smaller the count, the larger the shrimp”.

Size Name	Green headless	Peeled	Cooked
Extra Colossal	Under 10	Under 15	16/20
Colossal	Under 15	16/20	21/25
Extra jumbo	16/20	21/25	26/30
Jumbo	21/25	26/30	31/35
Extra large	26/30	31/35	36/40
Large	31/40	36/45	41/50
Medium large	36/40	41/45	46/50
Medium	41/50	46/55	51/60
Small	51/60	56/65	61/70
Extra small	61/70	66/75	71/80
Tiny	Over 70		

From Seafood Business Seafood Handbook, 1999

Seasonal Availability:

Seasonal availability varies with the fishery. As a worldwide commodity, fresh wild-caught shrimp from some source is always available. However, each local fishery is subject to seasonality, either because the shrimp are not catchable at certain times (due to harsh weather or to seasonal dispersal of the animals) or for regulatory reasons. For example, the brown shrimp *Penaeus aztecus* is available from U.S. fishers in the summer [12]. Atlantic white shrimp *P.setiferus* are harvested mainly in the fall, while pink shrimp *P. duorarum* are harvested in both spring and fall [12].

The availability of farmed shrimp is greatest in the autumn, as farms in many temperate areas harvest their yearly crop and then close down for the winter [22]. Tropical shrimp farms may harvest more than one crop per year, but even these tend to bring a crop to market in time for the

December holiday season, further increasing the shrimp supply in November and December. This abundant supply tends to push wholesale shrimp prices down [5].

Shrimp is scarcest in the early spring (late January through early March), when many northern fisheries are closed for the winter, temperate farms have yet to re-open, and tropical farms are still growing out their first new crop [5, 23]. Spring is when shrimp wholesalers expect the highest prices for their products.

Product Forms

Not only are there many varieties of shrimp for sale worldwide, but there is a great diversity in product forms. Product can be divided into two basic types: raw and cooked [21]. It can then be further divided into fresh and frozen [21]. Within these broad categories, almost all shrimp sold in the U.S. market is sold as head-off tails, and the bulk of that is sold frozen [21]. Primary product forms for frozen shrimp are:

Green Headless: The standard market form. Includes the six tail segments, with vein, shell and tail fin. "Green" does not refer to shell color but to the uncooked, raw state of the shrimp. Also called "shell-on" or "headless" [21].

Peeled: Green headless shrimp without the shell [21].

PUD: Peeled, un-deveined, tail fin on or off; raw or cooked. The vein, running the length of the tail, is the intestine, also called the mud vein or sand vein [21].

Tail-on Round: Undeveined shrimp with tail fin on [21].

*Frozen Products:*Frozen shrimp generally comes in two forms: blocks (shrimp frozen en masse) and individually quick-frozen (IQF) packs [21]. Both shrimp blocks and IQF shrimp are glazed with a protective ice coating to prevent dehydration [21].

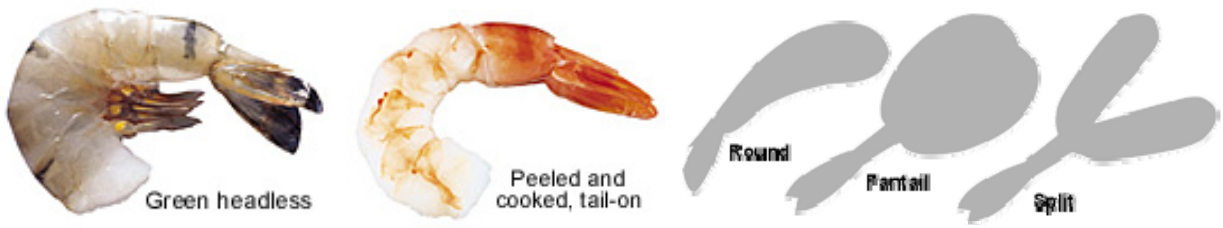
P&D: Peeled, deveined, tail fin on or off; raw or cooked. Another name for IQF P&D shrimp is PDI (peeled, deveined, individually frozen) [21].

Cleaned: Shrimp that is peeled and washed, a process that removes some or all of the vein but is not thorough enough to warrant the P&D label [21].

Shell-on Cooked: Cooked tail, with vein, shell and tail fin [21].

Split, Butterfly, Fantail: Tail-on shrimp that are cut deeply when being deveined[21].

Pieces: Shrimp with fewer than four or five whole segments [21].

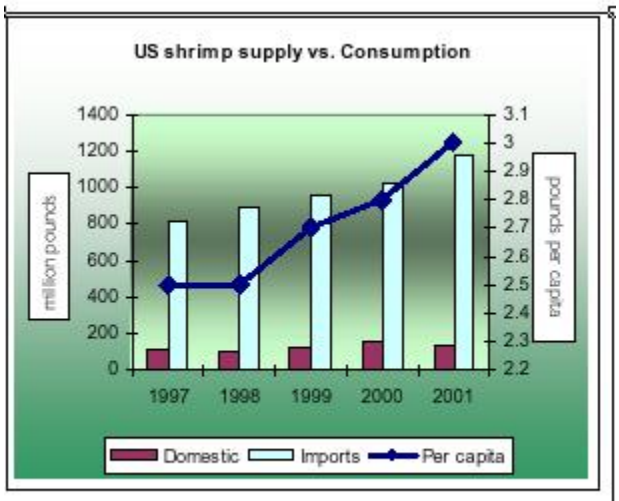


Images from Seafood Business Seafood Handbook, 1999.

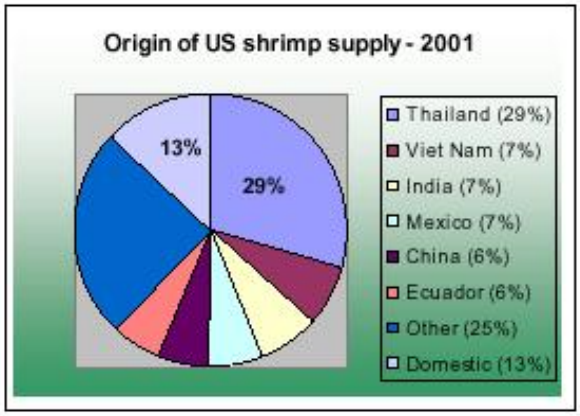
Import and Export Sources and Statistics:
The global shrimp market makes no distinction between warmwater and coldwater shrimp, farm-raised or wild-caught. However, data show that about 3/4 of world shrimp production is wild-caught, further broken down into 70% warmwater and 30% coldwater shrimp. The remaining 1/4 of total production is farm-raised shrimp [5, 6].

The U.S. imports more seafood than it exports; for several years, this trade deficit has been driven by what seafood market analyst H.M. Johnson calls "the tidal wave of shrimp imports" [5]. In 2000, imports of shrimp to the U.S. topped one billion pounds (heads-off weight) for the first time in history. That translates to 343,418 metric tons, with a wholesale value of about $3.7 billion. As of the latest figures available in 2003, about 87% of the U.S. shrimp supply was imported. This includes farmed and wild, warm- and coldwater- shrimp, with no way for the consumer to discern them [Cutland & Cherry, 2002]. So-called "value-added" or processed shrimp products are an important part of the import picture. Between 1997 and 2000, imports of breaded shrimp increased by 85% and cooked shrimp by 23% [5].

In 2001, the total U.S. shrimp supply was about 1.3 billion pounds (589,670 metric tons), including domestic landings of about 180 million pounds (81646.6 metric tons) [Cutland and Cherry, 2002]. Domestic landings thus accounted for about 13% of the U.S. shrimp market in 2001.



Source: National Marine Fisheries Service/National Fisheries Institute



Source: National Marine Fisheries Service

For many years, Thailand has been the leading supplier of imported shrimp to U.S. markets [Johnson, 2001]. In 2001, Thai shrimp accounted for 29% of the U.S. market [Cutland and Cherry, 2002]. Mexico, India, and Viet Nam tied for second place, with 7% each [Cutland and Cherry, 2002]. China and Indonesia also make substantial contributions to U.S. shrimp imports [5, 24]. In all, Asian nations account for 66% of America's imported shrimp [5, 24].

It is hoped that the advent of country-of-origin labelling (COOL) in autumn 2004 will help U.S. consumers discern the source of their shrimp.

The U.S. also exports some fresh and frozen shrimp, mainly to Japan and Canada [5]. In 2000, U.S. shrimp exports totaled $139 million, up from $123 million in 1999 [5].

Consumption Information and Trends:
Worldwide, shrimp consumption has been on the rise for more than a decade [25]. Demand for this luxury item shows no sign of slowing in the major markets of Japan, Europe and the United States. In the United States, shrimp has the unusual distinction of being the one seafood preferred equally in all regions of the country [26]. U.S. shrimp consumption rose in 2000 to 3.2 pounds per capita, up .2 pounds from 1999 [5]. These statistics, like the global shrimp market itself, make no distinction between warmwater and coldwater shrimp, farm-raised or wild-caught.

Analysis of Seafood Watch® Criteria

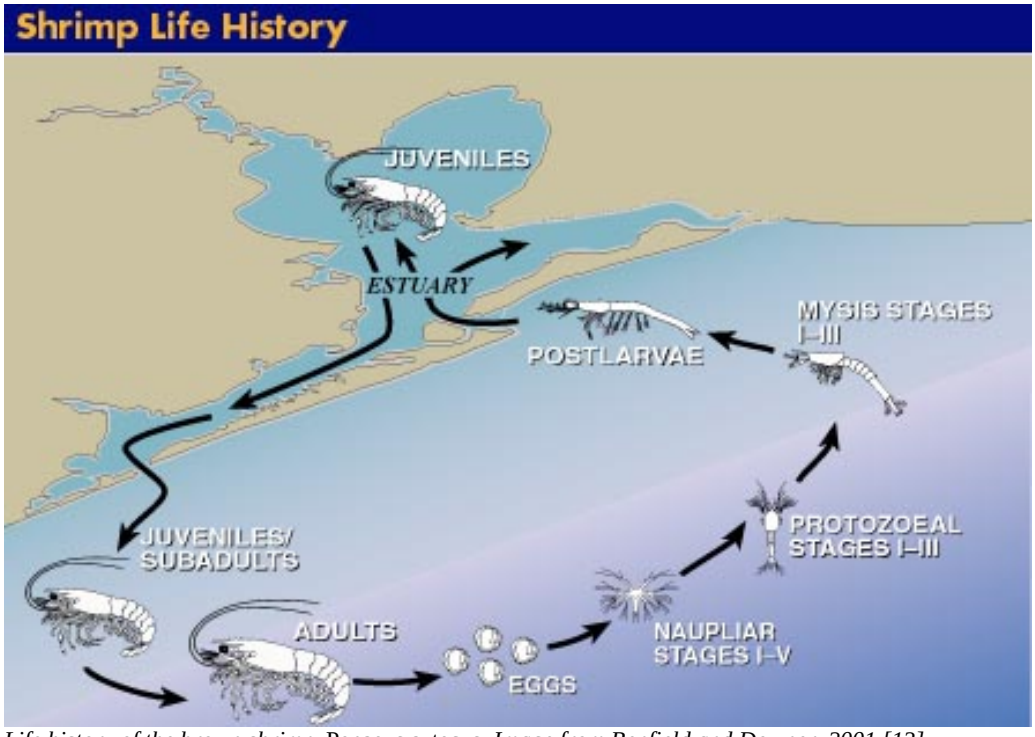
Criterion 1: Inherent Vulnerability to Fishing Pressure

Life History

Most shrimps are omnivorous, catching or scavenging whatever plant or animal material is readily available. The shrimp's intestine runs the dorsal length of its abdomen; it is the brown line sometimes called the "mud vein" on cooked shrimp. Like other arthropods, shrimps have no internal skeleton, being protected instead by a chitinous exoskeleton, which must be repeatedly shed as the animal grows [1]. The sexes are separate, and females tend to be larger than males.

Scientists have only recently discovered that penaeid breeding behavior starts at the onset of darkness [11]. The breeding season tends to run April-October. Males and females clasp to copulate, and females broadcasts fertilized eggs into the water column. Penaeid shrimp are extremely prolific; recent investigations reveal that each female lays about 217,000 eggs per spawn, and can spawn as often as every three days [11]. The tiny eggs drift with the plankton and may settle to the seafloor. Eggs hatch within 24 hours [11]. Newly-hatched shrimp larvae bear little resemblance to their elders; each must undergo up to 12 molts to attain final form as a juvenile shrimp. The tiny shrimp larvae are important food for many fishes and invertebrates [1]; those that escape predators and find favorable currents may live long enough to reproduce. Many of the warm-water penaeids are short-lived species, completing their life cycle in 18-24 months [12].

This diagram of penaeid life history is typical of many commercially-harvested shrimp species. It takes between 10 days and three weeks for penaeid shrimps to complete the transformation from newly-hatched nauplius to postlarva [11].



Life history of the brown shrimp, Penaeus aztecus. *Image from Benfield and Downer, 2001 [13].*

Distribution and Habitat

Penaeid shrimp are distributed throughout the warm oceans of the world. Postlarvae seek sheltered estuaries in which to grow to adulthood [11], making estuary habitat very important to many penaeid species. The annual abundance of penaeid shrimp is closely tied to natural factors (such as average temperature, amount of rainfall, and the number and intensity of storms) which affect the survival and recruitment of larvae [14]. Young penaeids are sensitive to changes in water salinity. Upland development and loss of wetlands increase the amount of fresh water entering nursery estuaries and can decrease juvenile survival [14].

Synthesis

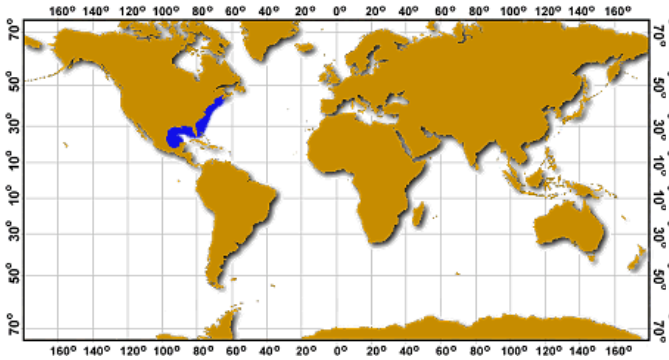
The life history of penaeid shrimps makes them inherently resilient to fishing pressure. Penaeid shrimps are short lived, quick to mature, and spawn prolifically. Young penaeids are sensitive to changes in water salinity and can be affected by runoff into to estuarine nursery habitat. However, overall concern regarding their vulnerability to fishing pressure ranks “low”.

Inherent Vulnerability Rank: **Low** Moderate High

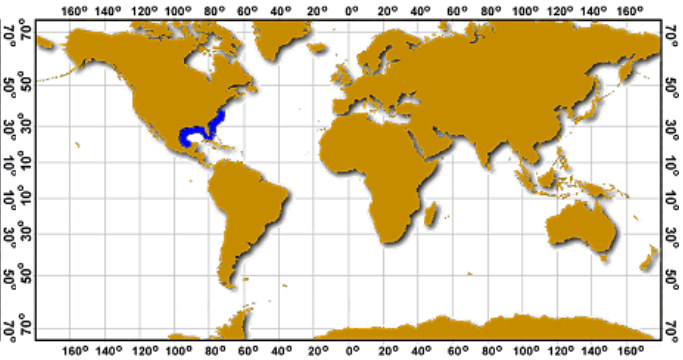
Criterion 2: Status of Wild Stocks

Fishery Range and Distribution

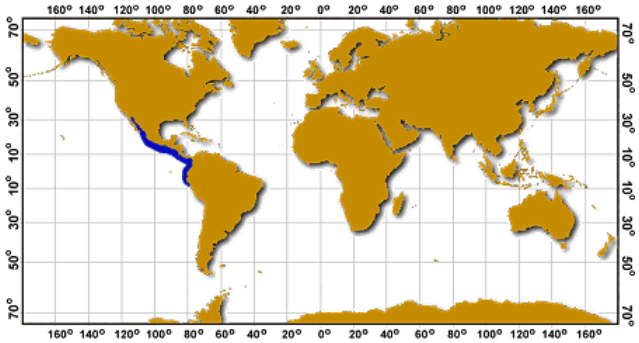
Warmwater shrimp are heavily exploited wherever they are found. Below are range maps for several of the most important commercial species, with an emphasis on those found in U.S. fisheries. All U.S. Gulf Coast and several South Atlantic states have warmwater shrimp fisheries [27].



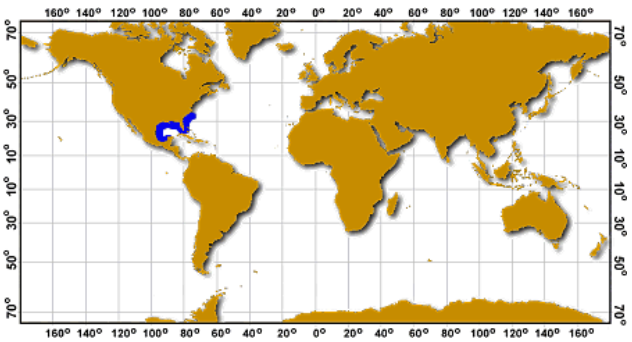
Distribution of *Penaeus aztecus*, brown shrimp



Distribution of *Penaeus setiferus*, Atlantic white shrimp



Distribution of *Penaeus vannamei*,Pacific white shrimp



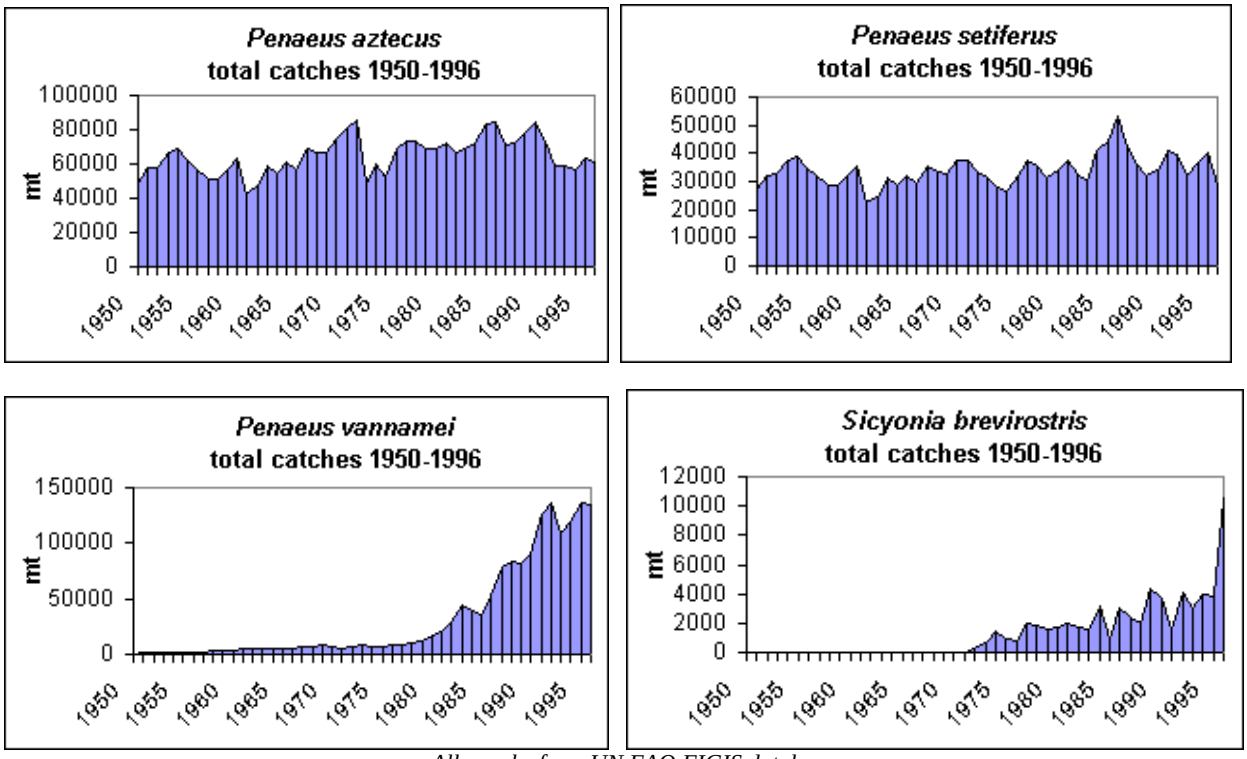
Distribution of *Siconia brevirostris*, rock shrimp

Graphs courtesyUN FAO FIGIS database

In addition, many U.S. fishers trawl in offshore waters along the Pacific coasts of southern California, Mexico and Central America [28]. Other nations with substantial warmwater shrimp fisheries include India, China, Malaysia, Thailand, Australia, New Zealand, and Japan [6].

Fishing Effort and Trends:

Everywhere warmwater shrimp are found, they are heavily fished. While most species show no **clear** signs of overfishing, most are believed to be exploited at or near their maximum sustainable yield (MSY) [25, 27].



All graphs from UN FAO FIGIS database.

Status of the Stocks?

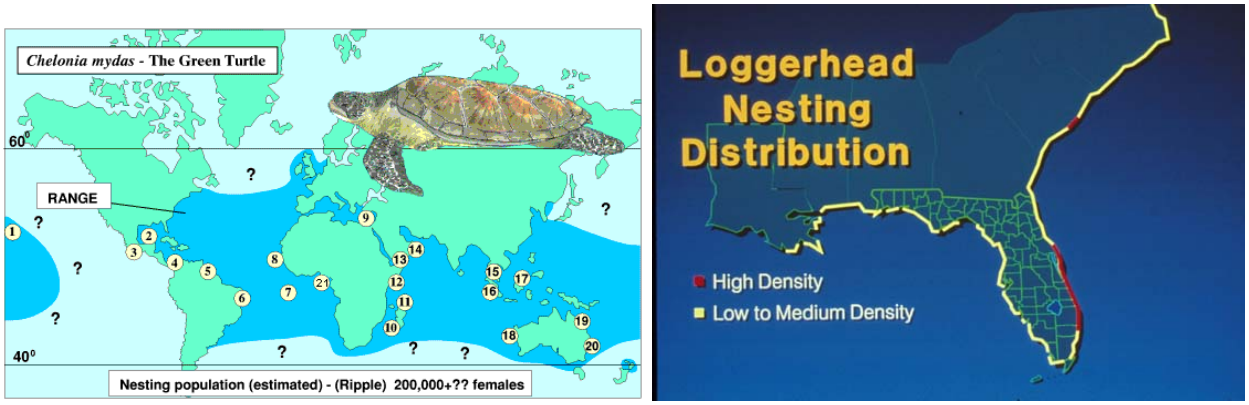
Status of the Wild Stocks Rank: **Low** ☐ Moderate ☐ High ☐

Criterion 3: Nature of Bycatch

Fishing Methods

Warmwater shrimps are taken almost exclusively with various kinds of bottom-trawl nets [6]; these include the double-rigged shrimp trawler, developed in the Gulf of Mexico and now the main trawling method used by the U.S. offshore shrimp fishery [29]. Such a rigging allows the same total net spread as one large net, but takes considerably less effort to pull [29].

Shrimp trawlers in the Gulf of Mexico favor a tall, high-mouthed net, due to the fact that the shrimp they seek tend to rise off the bottom and swim when disturbed [28]. While this design has been adopted by West Coast trawlers as well, Faulkner (2002) suggests that low-rise, wide-mouthed nets might be more appropriate for Pacific warmwater shrimps. These species scoot along the seafloor when disturbed, and so a wide-mouthed net is more appropriate for their capture [28]. Faulkner notes that such wide-mouthed nets also reduce drag through the water, saving boat fuel, and reduce the unwanted catch of finfish, which tend to rise to get away from the net [28]. This is just one example of a gear innovation proposed by a member of the shrimping industry. As economics and environmental concerns impact fishermen, there is a constant level of grassroots innovation by fishermen and managers to create new gear solutions [19]. Shrimpers off the Georgia coast have long faced hazards from floating debris (including 50-gallon drums and discarded washing machines)[30]. As a result, they have been motivated to add "trap-doors" to the nets, allowing not only debris but also sea turtles to escape the mesh. Formally known as "turtle excluder devices" (TEDs), these trap doors are now required on U.S. shrimp nets [31]. However, in some areas, the largest mature loggerhead and leatherback turtles are too big to fit through the opening of a standard-sized TEDs [32]. Because of the large-debris hazards in their area, Georgia fishermen tend to use TEDs with the largest available opening [30], which has the environmental benefit of permitting even the largest turtles to escape [32].



Distribution of endangered sea turtles, with emphasis on the Gulf of Mexico.

Bycatch, the unintentional take of non-targeted fishes and invertebrates, is a major concern in shrimp fisheries. The trawl method has great potential for unselective fishing. The UN FAO estimates that 35% of the world's incidental catch occurs in shrimp trawl fisheries [Alverson et al. 1994; Steiner 1996]—about 10 million metric tons per year. The world's shrimp fisheries produce only about 2% of global seafood [Alverson et al. 1994; Alverson, 1998; EJF, 2003], but are responsible for 30% of world bycatch. In many developing nations, the small fish, crabs, and other species caught along with shrimp are landed and utilized for human or animal food, and cannot be considered "bycatch" [Hall, Alverson & Metuzals, 2000; EJF, 2003; Jones, 2003]. However, in other fisheries, the non-shrimp catch of shrimp trawls is tossed overboard [NMFS, 1998; Jones,

2003]. Having been trawled up, dumped on deck, stepped on, sorted through, and left in the sun while the shrimp are collected, by the time these animals are thrown overboard, most are dead or dying [NMFS 1998].

The amount of bycatch taken per fishery depends partly on the behavior of the target shrimp. For example, Australia's northern prawn fishery takes large quantities of banana prawns *(Penaeus merguensis)*, but this is a low-bycatch fishery because these prawns aggregate in single-species shoals. The same fishery, using essentially the same gear, also targets the tiger prawns *Penaeus esculentus* and *P. semisculatus*, which disperse instead of shoaling. A haul of tiger prawns from this fishery usually involves heavy amounts of bycatch [6].

Penaeid shrimps mix with fish bycatch in Gulf of Mexico trawl fisheries. Photo courtesy University of Louisiana.

Endangered sea turtles continue to die in fishing gear. Photo courtesy Sea Turtle Restoration Project.

Sea Turtle Bycatch

Perhaps the issue of greatest concern in warmwater shrimp fisheries is the accidental take of sea turtles in shrimp trawl nets [Buck, 1997]. “Take”, as used here and in management literature, refers to any interaction of turtles with fishing gear, whether the turtle was killed or not; take events range from minor and survivable entanglements to death by drowning. In 1996, conservation biologists estimated that 50,000 turtles were caught in U.S. waters; 60,000 were caught in Central American shrimp fisheries [Steiner, 1996]. These numbers may have improved recently; take in Central American shrimp fisheries can be estimated at around 40,000 turtles per year [Steiner, 2004]. These are only the fisheries with the best observer coverage; the same groups estimated that several hundred thousand turtles were being killed each year in the shrimp fisheries of Asia, South America, Mexico and Africa [31]. Already under threat because of development of their nesting habitat, species such as the leatherback turtle (*Dermochelys coriacea*), Kemp's ridley *(Lepidochelys kempii)*, and

green sea turtle (*Chelonia mydas*) are considered endangered species under both U.S. law [33] and international convention [34]. The loggerhead turtle (*Caretta caretta*) is considered threatened under U.S. law [33].

There is a technological solution that can reduce the take of sea turtles in shrimp nets: a trap-door grate, called a turtle-excluder device (TED), which allows turtles to push free of the net. Shrimp, meanwhile, pass through the slots in the grate and collect at the back of the net. Studies by the U.S. National Marine Fisheries Service (NMFS) show that 97% of turtles caught in TED nets can escape [35]. Meanwhile, the shrimp take is reduced—by as much as 30%, some fishermen claimed, although federal government tests indicated an average of 10% [15]. Some U.S. fishermen were behind the idea of TEDs from the beginning; the earliest TEDs were designed by fishermen to keep unwanted catch out of their nets. Many were concerned with "jelly balls"--aggregations of jellyfish--the fact that the grates released sea turtles was an additional benefit. Nonetheless, other fishermen resisted the idea of putting an escape hatch on their nets [15]. It took legal action under the Endangered Species Act to compel NMFS to require TEDs on all U.S. shrimping vessels operating in the Gulf of Mexico and south Atlantic [31, 36]. Since 1990, all U.S. warm-water shrimpers have been required to use TEDs [31]. In 1992, the provision was extended to foreign fleets: all trawl-caught shrimp sold in the United States was to be from fleets that required TEDs [31].

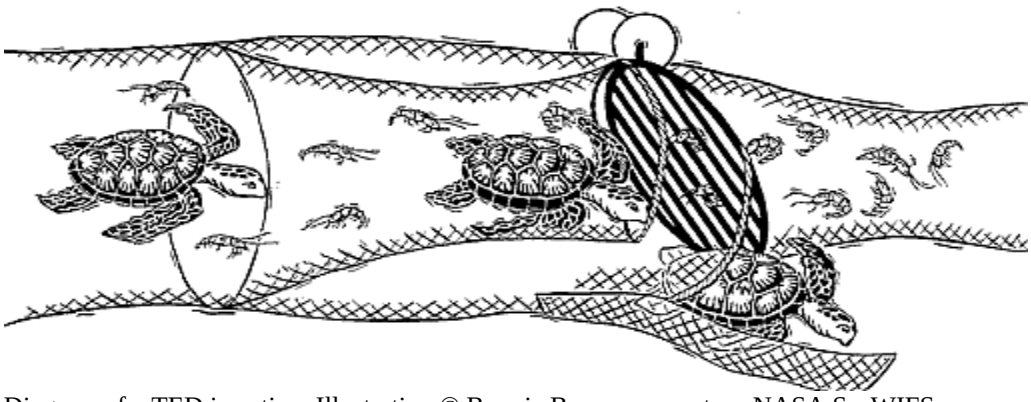


Diagram of a TED in action. Illustration © Bonnie Branner , courtesy NASA SeaWIFS.

The new TED regulations appear to be working; in 2001, biologists estimated that the take of sea turtles in shrimp trawl nets had been reduced to perhaps 150,000 per year [AIDA, 2001], including 62,000 loggerheads and 2,300 leatherbacks [Federal Register, 2003]. While “take” means both lethal and non-lethal interactions, this level of take is still a huge threat to endangered turtle populations. In 1996, four Asian nations (Malaysia, India, Pakistan and Thailand) filed a complaint before the World Trade Organization, alleging that the U.S. law created an unfair trade barrier [37, 38]. The issue has been in and out of court ever since [15, 39]. The United States now follows a system wherein shrimp from nations that require TEDs are blanket-certified, while shipments from nations that do not require TEDs are certified on a shipment-by-shipment basis [37, 39]. This compromise is criticized by environmentalists, who argue that, in many nations, enforcement of TED laws is lacking and that the law has failed to stop the deaths of rare turtles [AIDA, 2001]. There are reports from conservation workers that, in many Central American nations, shrimp-boat inspections for TED use are announced days in advance to the boat captains. Conservation workers report that an “inspection” often consists of the government officers pulling up to the shrimp boat, receiving a bag of fresh shrimp, and going on their way [Steiner, 2002].

According to Steiner, 2004, “cheating (on TED laws) is universal” in Central American shrimp fisheries, and enforcement is suspect in Asian and Indian shrimp trawl fisheries as well [Steiner, 2004]. Meanwhile, U.S. shrimp fishermen believe they are suffering the economic consequences of being held to a higher ecological standard than fishermen in other nations [Buck, 1997; Halbfinger, 2003].

In 1999, in an effort to connect U.S. fishermen with environmentally-conscious consumers, the Sea Turtle Restoration Project launched the "Turtle-Safe Shrimp" certification program. Only shrimp caught by U.S. fishers who pledged to use TEDs, or fished outside of sea turtle habitat, were eligible. Sea Turtle Restoration Project provided chain-of-custody monitoring from boats to retailers. However, in early 2001, this program was discontinued due to a lack of funding [40]. A cooperative of Georgia fishermen, once the backbone of the "Turtle-Safe" program, continue to catch shrimp using the "turtle-safe" methods (including use of the largest TEDs); this group now markets their catch under the brand name "Georgia Sweet"[30].

Finfish and Non-Endangered Bycatch

In recent years, much research has been devoted to documenting levels of bycatch in warmwater shrimp fisheries [Alverson et al. 1998, Graham 1996; Alverson 1998]. Bycatch of commercially-important fishes [Harris and Dean, 1998; Graham 1996], as well as other marine life [Buck, 1997; Hall, Alverson, and Metuzals, 2000] is of concern in many of these fisheries. International conservation organizations and several of the larger scientific journals have published general articles detailing the problem and highlighting potential solutions [Clucas 1997; Alverson et al. 1998, Alverson 1998; Hall, Alverson & Metuzals, 2001; EJF, 2003]. On a worldwide basis, shrimp trawl fisheries have the highest discard/catch ratios of any fisheries [Hall, Alverson & Metuzals, 2000]. Alverson et al. (1994) found that 14 of the world’s 16 worst bycatch-to-catch ratios were found in shrimp trawl fisheries. Worldwide, bycatch ratios for shrimp trawl fisheries range from about 3:1 to 15:1 (kg discarded to kg landed) [Hall, Alverson & Metuzals, 2000], with one of the worst large fisheries being that of the Gulf of Thailand, at 14:1 [Clay, 2002].

Synthesis

Most tropical shrimps are captured by bottom trawling methods which take high levels of bycatch, including finfish, other commercially important fishes, and significant numbers of endangered and threatened sea turtles. While technological innovations such as the turtle-excluder device (TED) have reduced bycatch in recent years, not all countries that operate shrimp fisheries require or enforce the use of TEDs. In addition, shrimp trawl fisheries take the world’s highest levels of non-endangered bycatch (finfishes, sharks, invertebrates, etc.). Because of the severe and continuing threat to endangered and threatened sea turtles from trawling gear, and the heavy bycatch of finfish and other creatures associated with tropical shrimp trawling, international shrimp trawl fisheries rank of critical conservation concern for Nature of Bycatch.

Nature of Bycatch Rank: Low ☐ Moderate ☐ High ☐ **Critical** ☐

Criterion 4: Effects of Fishing Practices on Habitats and Ecosystems

Warmwater shrimps are taken almost exclusively with various kinds of bottom-trawl nets [Clucas, 1997]. The environmental damage caused by bottom trawling can be substantial and irreversible [Watling & Norse, 1998]. Bottom-trawl nets can plow deep furrows in the seafloor, remove rock and coral, stir up sediments that smother benthic organisms, and smooth out natural topography until the seafloor resembles a plowed field [Pilskaln et al., 1998; NRC, 2002]. Moreover, many areas are trawled several times per year, allowing no time for bottom fauna to recover its pre-trawled condition [Watling & Norse, 1998]. Shrimp trawling is widely suspected of causing habitat damage, although this usually takes a back seat to bycatch issues in reviews of shrimp trawling [Dayton, Thrush and Coleman, 2002; NRC, 2002; Morgan & Chuenpagdee, 2003; EJF, 2003]. Bottom trawling has been found to significantly reduce habitat diversity where habitat was diverse to begin with, such as along the Central California coast [Engel & Kvitek, 1998]. Bottom-trawling has been shown to change the relative abundance of bottom-dwelling organisms, favoring fast-growing, opportunistic species and decreasing the abundance of slow-growing, low-fecundity species [Simboura et al., 1998; Schwinghammer et al., 1998]. While overall biodiversity often decreases under heavy trawling, the bottom-trawl regime can increase the abundance of certain “desirable” organisms, such as shrimp themselves [Simboura et al., 1998] or prey for commercial fish species [Engel & Kvitek, 1998]. In general, the environmental effects of bottom trawling appear to be most severe on coral reefs, rocky substrates, and deepwater areas subject to little natural disturbance [Watling & Norse, 1998; Schwinghammer et al., 1998]. Bottom trawling seems to have the least effect on environments already adapted to much natural disturbance, such as sandy substrate disturbed by frequent storms [Schwinghammer et al., 1998; Barnette, 2001].

It should be noted that shrimp trawling does not seem to harm the abundance of the commercially-important shrimps themselves. In fact, one study in the Aegean Sea found shrimp abundance increasing as a result of the substrate changes caused by shrimp trawling [Simboura et al., 1998].

Synthesis
Bottom trawling for shrimp can have a severe impact on the marine habitat. If the area trawled is coral reef or other rocky substrate, the habitat can be damage beyond repair by bottom trawling. If, on the other hand, the habitat trawled is sandy or muddy bottom, the impact to the benthic habitat may be minimal. The effects on habitats and ecosystems from bottom trawling rank “moderate”.

Effects of Fishing Practices Rank: Low ☐ **Moderate** ☐ High ☐

Criterion 5: Effectiveness of the Management Regime

Management

Despite the international trade in shrimp products, there is no international management agreement covering shrimp. Nations manage shrimp fisheries in their Exclusive Economic Zones (EEZs) as each sees fit.

In the U.S., individual state fisheries regulate the nearshore shrimp fishery (0 to 3 miles offshore). The U.S. National Marine Fisheries Service (NMFS) manages fisheries in the waters of the U.S. Exclusive Economic Zone (EEZ), from 3 to 200 miles offshore. NMFS has the authority to set catch limits and fishing-season openings and closings. U.S. warmwater shrimp fisheries are covered under the Fisheries Management Plans of the Gulf of Mexico and the South Atlantic region [27]. NMFS and state authorities conduct periodic stock surveys on shrimp populations. In many fisheries, this includes annual or seasonal trawl surveys [41].

Enforcement

As with management, enforcement of shrimp regulations is in the hands of the individual nations that operate shrimp fisheries.

In the United States, NMFS and the U.S. Coast Guard collaborate to conduct dockside catch surveys and at-sea inspections, enforcing catch restrictions and the regulations concerning the use of TEDs. NMFS on-board observers are employed in Southeast Region otter-trawl shrimp fisheries; the program is voluntary and NMFS estimates that less than 1% of fishing hours are covered by observers [42].

In many nations, inspections for TED use are conducted only every few years and are always announced to the fishermen well in advance [37].

Synthesis

The management and enforcement of shrimp fishery regulations and TED requirements is the responsibility of each nation that operates a shrimp fishery; there is no international management agreement regarding shrimp. Many countries do not sufficiently enforce TED use. Due the lack of sufficient management in international fisheries, the Effectiveness of the Management Regime criterion is given a rank of “high” conservation concern.

Effectiveness of Management Rank: Low ☐ Moderate ☐ **High** ☒

Overall Evaluation and Seafood Recommendation

Warmwater shrimps (the penaeid shrimps) supply approximately 80% of the world's wild-caught shrimp. Penaeid shrimps are inherently resilient to fishing pressure. Penaeid shrimps have a short life span, reach maturity within a few months, and spawn prolifically. Wherever penaeid shrimps are found, they are exploited at or near their maximum sustainable yield. Most warmwater shrimp fisheries use bottom trawl gear which take high levels of bycatch. Shrimp trawl bycatch includes ecologically significant numbers of finfishes, sharks, and invertebrates, as well as endangered and threatened sea turtles. While technological innovations such as turtle-excluder devices (TEDs) and finfish bycatch reduction devices (BRDs) have reduced bycatch recent years, not all fisheries use them, and, even where their use is required by law, enforcement is often lacking. Regulation of shrimp trawlers is in the hands of each nation that operates a shrimp fishery; among the many nations that catch tropical shrimp, management and enforcement measures vary widely. Several nations recently went before the World Trade Organization to challenge U.S. laws designed to ensure that all shrimp imported into the U.S. is caught using TEDs. Even where TEDs are employed, bycatch of finfish and invertebrates remains high. Bottom trawling can also have severe effects on seafloor habitat (depending upon the type of habitat trawled). As of the latest figures available in 2003, about 87% of the U.S. shrimp supply was imported. This includes farmed and wild, warm- and coldwater- shrimp, with no way for the consumer to distinguish between them. It is hoped that the advent of country-of-origin labelling (COOL) in autumn 2004 will help U.S. consumers discern the source of their shrimp. For concerns with bycatch, habitat loss and management, the overall seafood ranking is **"Avoid"** for imported, bottom-trawled warmwater shrimp.

Table of Sustainability Ranks

Sustainability Criteria	Concern: Low	Concern: Medium	Concern: High	Concern: Critical
Inherent Vulnerability	√			
Status of Stocks	√			
Nature of Bycatch				√
Habitat Effects		√		
Management Effectiveness			√	

International trawl-caught warmwater shrimp:

Overall Seafood Rank: **Avoid**

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