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Full Length Article

Biodiversity and Fisheries Assessment of the Indus Delta Creek System, Pakistan: A Qualitative and Quantitative Analysis of Fish and Shrimp Species and Fish Stock Biomass Estimates

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Abstract

The intricate network of rivers, estuaries, mangroves and Indus delta creeks that make up the Sindh coastal region is notable for its significance to the rural population's way of life. Thirteen of the seventeen streams in the Indus Delta were surveyed for the Indus Delta project between June 2013 and May 2014. Out of the 583 samples collected from the study area, 241 species have been identified from the study area of the Indus Delta. There were notable variations in the monthly frequency of fish catch (kg/hr) tow, particularly prior to and during the monsoon season. Fish samples are divided into groups according to their habitat. Of these, 75% are found in estuaries, followed by marine fish species (23%) and freshwater fish species (2%). The primary families of fish were Clupeidae, Engraulidae and Mugilidae; the species with the highest availability in the stream region is *Escualosa thoracata*. The estuary productivity was highest at Wari Creek, while the marine productivity was highest at Richhal Creek, according to the spatial variance in estuarine, marine and freshwater capture. The correlation between the parameters of water quality and catch indicates that the average temperature fluctuations in the research region are not as significant as those in average salinity and depth. The creeks to the west of Jhang River have become more saline and have shallower depths. Due to their high migratory activity and propensity to shift habitat, estuarine stock was more negatively impacted by this condition than marine fish species. Using the swept area approach, the biomass estimates of the fish abundance stock were calculated. It was discovered that the distribution is skew and the index of abundance is not normally distributed. With an estimated biomass of 9,594 MT, which is 16.61% of the calculated biomass of 57,750 MT in 1986, it was demonstrated that creek areas of the Indus Delta are equally substantially overfished, similar to other coastal and offshore waterways in the country.

Keywords: Indus delta; Creek system; Biodiversity; Qualitative and quantitative analysis; Biomass estimates

Introduction

Pakistan's coastline is 1001 km long, which forms the northern border of the Western Indian Ocean. The Balochistan coast is 734.5 km long, whereas the Sindh shore is 266.5 km long (PN-hydro 2016). The delta of the sixth-largest Indus River in the world is one of the many intricate networks of rivers, estuaries and mangroves that define the coastal region of Sindh (Rizvi and Fanning 2012). Between 1973 and 2021, the yearly growth rate of fish production was 4.9%; however, the marine sector's growth rate was just 2.4% (Khan and Abbas 2023). There have been signs that several important resources, such as shrimp, lobster, sharks, crabs, etc., have already been overfished and are at risk of becoming unsustainable. Therefore, there was a need to have updated information about fish stocks was essential for the nation's fisheries to be managed sustainably (Raza and Khan 2001).

The purpose of the stock assessment research was to gather up-to-date data on the principal marine resources in Pakistani waters and to make recommendations for future management that would maximise the long-term viability of the fisheries. Pakistan's marine fisheries feed a significant portion of the one million people who live along the shore, especially in the Indus Delta, with food, cash and foreign exchange. The researchers came to the conclusion that Pakistan's marine fisheries were either overfished or completely exploited. Thus, surveys of fish stocks in the Pakistan Exclusive Economic Zone's offshore waters were carried out from 2009 to 2015. This study's creek survey was a component of the Fisheries Resource Appraisal in Pakistan (FRAP) project (Rizvi and Fanning 2012).

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A complex network of waterways includes the delta of the Indus River, which is the sixth-largest river globally, estuaries and mangroves that make up the coastal region of Sindh (Damhoureyeh and Ghalib 2014). The Indus Delta is essential to the region's ecology, economics, environment and way of life for its residents. The estimated seventeen distributaries constitute the heavily branching Delta. One of the most frequently occurring landforms in the region is made up of immense mud planes broken up by minor rivers that are the last surviving tributaries of the Indus. It's situated on Karachi's southwest border. The primary outlet to the sea is Khobar Creek; freshwater water is only supplied by the Indus River to the region between the Hajamro and Kharak Creeks (Amir *et al*. 2016).

The average surface water temperature in the Indus Delta is 21.8°C, with an average yearly temperature of 29.0°C, a 76% relative humidity on average and about 220 cm of rain on average. When seawater reaches the active and inactive parts of the delta during the summer, evaporation occurs when there is a high salinity in the seawater and a low salinity delta. Consequently, there are still salt deposits that are evaporating. The Indus River discharges into the Arabian Sea after passing through the Delta, is the previously mentioned source of perennial freshwater. Freshwater vegetation is typically found in creek pockets. There is hardly little rain on the 150 km wide Indus Delta shelf during the monsoon season. Throughout these months, the wind speed ranges from 12 to 35 km per hour on average (Damhoureyeh and Ghalib 2014). Brackish-water prawns and fish species use the delta's lush coastline and abundant marine biodiversity as a nursing and early feeding site for their flora and fauna. The nutrients that are absorbed by the river and the sea are the first in this "food web" (Memon 2005). In these isolated coastal villages, 90% of the population makes its living only from fishing (WWF 2005, 2007). Fish fauna samples were regularly collected from several creeks during the survey period, as detailed in the materials and methodology for a qualitative study of fish species biodiversity.

FRAP project operations revealed that the number of fishing vessels, their level of automation and their duration at sea had all increased. Commercial fishing must be limited, or its location and effort must be managed to avoid overexploitation. A substantial reduction in fishing activity will be required to recover the most valuable marine resources in the near future (Fanning *et al*. 2016; Khan and Abbas 2024). This paper describes the qualitative and quantitative analysis of the data gathered during the creek survey and has provided estimates of abundance and the biomass of fish stocks in the creeks.

Material and Method

Fish sampling and stations

The creek survey is classified as small-scale trawl surveys connected to the coastal and offshore surveys according to the FRAP project document's plan. A trawl survey strategy, as utilised in more open waterways, is likely to be severely limited in terms of both space and taxonomy due to the size and complexity of the stream habitats. Combining a multi-gear sampling program with an alternative approach based on habitat mapping and classification was thought to provide a more thorough approach, utilising technical and analytical advancements in GIS and remote sensing to plan, carry out and enhance a field sampling program. SUPARCO has carried out a preliminary categorisation of the habitats using the available remote sensing imagery. Remote sensing was used for the classification of digital watercourse polygons. Among the parameters are the creek's width, distance from the sea and the land classification next to it. Google Earth is a web-based tool for visualising several aspects of the digital data. The pilot phase involves the selection of specific sample locations within each research region. The purpose of the sites is to represent the variety of circumstances (substratum, coastline, tides and currents and bathymetry) throughout the research region (Rizvi and Fanning 2012).

Study areas and sampling stations

Every research region is delineated by the high tide level and is plotted using Google Earth's projected digital high-water lines. Following preliminary bathymetry, certain sample sites are chosen and designated with pairs of GPS waypoints to define primary channel sections. Trawl samples are collected as near the line connecting the waypoints as feasible within the intended depth ranges. The overall area, distance from the sea, duration of the survey, percentage of the survey and number of stations in each chosen stream are all listed in Table 1. Sample sites are located along several creeks, as seen in Fig. 1A.

Type of trawl nets employed for sampling

The Creek Surveys employed two types of trawl nets; a 16' SKT Model 38 bottom trawl and a 25' Mamou surface or pelagic trawl. These two trawls are deployed using comparable techniques and the catch is processed on deck and in the lab in the same way. Both trawls utilise the same tow lines and door connections.

i) **Bottom trawl:** The SKT (model 38) trawl net is a compact bottom trawl that may be used with or without winches and is appropriate for small boat deployment. To ensure tight bottom contact, the design has a chain-weighted bottom rope. Trawl tows will be aimed for a 20 min period at 3.0 to 3.5 kts (5.6 to 6.5 km h^{-1}), covering 1.5 to 2.0 km each tow.

ii) **Pelagic trawl:** The Mamou Surface Trawl is a basic piece of equipment that enables a small boat with no winches and little horsepower to tow on the surface and collect samples of tiny to medium-sized fish. Specifically, it

Table 1: Survey details include the total area, distance from the sea, survey length, proportion of survey and number of stations in each selected creek. (Source: Rizvi and Fanning 2012)

NAME	AREA (km2)	DIST SEA (km)	LENGTH (km)	PROP	STNS
Chann Creek	20.7	1.04	6.65	26.50	10
Hajamaro creek	2.208	1.64	2.26	2.83	3
ShahBandar 2	9.018	2.20	3.60	11.55	6
Shahbander	2.684	2.24	2.48	3.44	4
Dabbo Creek	7.355	4.09	4.01	9.42	5
off Paittiani Creek	5.035	5.25	2.93	6.45	4
Richal Creek	0.236	6.55	1.08	0.30	3
Waddi Khuddi Creek	20.541	7.56	6.01	26.30	10
Upper Paittiani Creek	0.741	20.21	1.37	0.95	3
Rahppato	0.421	21.04	0.91	0.54	3
River Indus Site	2.685	27.48	2.64	3.44	4
Upper Dabbo Creek	2.394	27.58	1.90	3.07	3
Upper Chann Creek	0.421	28.12	0.78	0.54	3
Khajar Creek	2.738	35.50	3.40	3.51	4

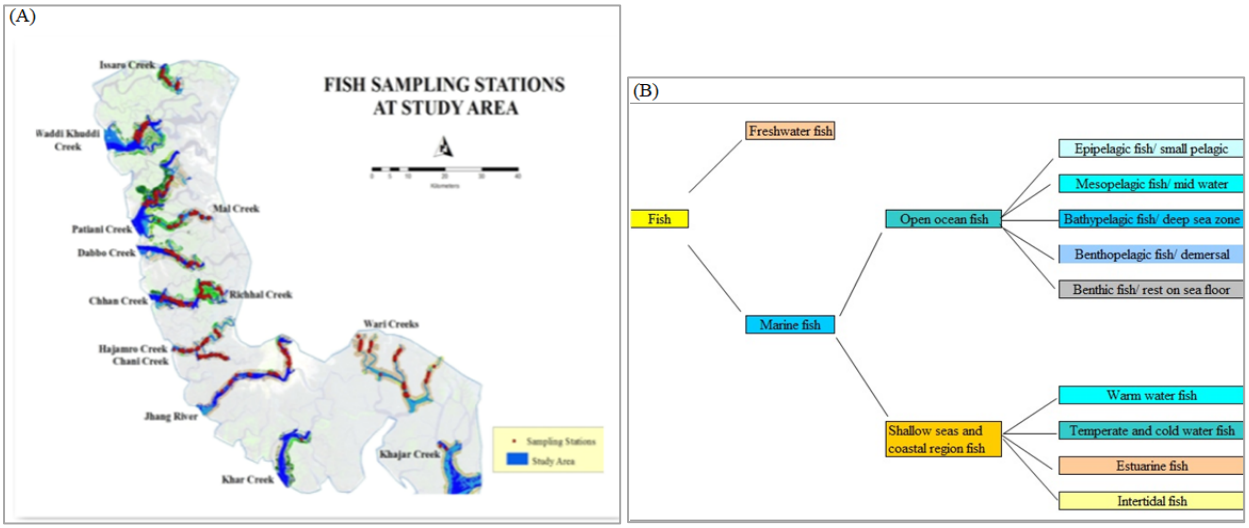

Fig. 1: (**A**) Fish sampling station in the Indus Delta creeks and (**B**) Habitat based fish classification

is made for surface and epi-pelagic trawling. It is designed to float over obstructions and roots without making touch with the bottom. The trawl is 7.6 m (25') wide and uses 36" mid water "Mullet" trawl doors to collect samples from the surface down to 3.25 m. Halter lines can be used to restrict the descent of the fishing circle (the net's mouth opening) below the headline, so limiting fishing to a predetermined depth of 2.5 to 3.25 m. Trawl tows will travel 1.5–2.0 km per tow with a goal length of 20 min at 3.0–3.5 kts (5.6–6.5 km h^{-1}).

iii) **Trawl doors:** To spread the sides of the trawl open, both trawls employ plywood doors with steel runners and chain bridles. Additionally, the surface trawl doors have floatation tanks made of PVC pipe, which makes them easily identifiable. The four door chains are collected onto a tiny shackle on both trawl door models and they are then attached to a swivel. The yellow polypropylene tow ropes are fastened to the trawl doors' swivel using an additional shackle.

iv) The CTD-Castway was used to gather environmental samples; a hand reel was used to deploy and recover the device. The instrument's specifics are provided in Rizvi and Fanning (2012) and Khan and Abbas (2020).

Fish sampling and identification

Fish was sampled using both bottom and pelagic trawls. Fish stock studies were carried out as part of the Fisheries Resource Appraisal project's watercourse survey between May 2013 and June 2014. The data was then analysed in a GIS environment to get the temporal and geographical distribution of fish species that had the largest concentration of both pelagic and demersal fish species. For fish, the lengths were expressed as total length (TL) and fork length (FL) in centimetres, while for prawns; the measurements were made as total length (TL) and carapace length (CL). For every species, kilogramme was the weight measuring unit. According

to Tirmizi and Bashir (1973), Fischer and Bianchi (1984), Froese and Pauly (2021) and WoRMS (2024), species were recognised. The two main classes of fishes are freshwater and marine, with other classifications dependent on the maritime environment, including coastal, shallow and open sea. In the open ocean, fish species are further divided into three groups: demersal, mesopelagic and pelagic (Fig. 1B). According to their environmental habitat, fish species are classified as freshwater, marine, or estuarine.

Catch standardization

Results were adjusted to a standard tow (tow duration = 60 min and spread = 7.86 m as the rigging of the trawl net) due to the variance in towing time and net spreads (horizontal distance between the wingtips of the trawl) amongst the various hauls using the following formula:

$$C(S) = W \times 60 \text{ min}/t \times C$$

Where:

- C(S) is the standardised catch rate
- C is the catch weight during each tow
- W is the net spread and
- t is the tow duration in each haul.

Fish abundance and fish biomass estimation

Fish biomass was estimated using the swept area approach described in Abildgaard *et al*. (1986). The maximum towing period was 30 min, with each tow travelling 1.5 to 2.0 km at a speed of 3.0 to 3.5 kts (5.6 to 6.5 km h^{-1}). The catchability coefficient was q = 1, the net width and height measured were 7.6 x 3.25 m and the towing distance was 1.5 nautical miles. The swept area method assumes that the trawl net is perfectly efficient at capturing all fish within its swept area, meaning that every fish within the area is caught, thereby making the "q" value equal to 1. As a result, "q" is frequently taken to be 1 in simplified calculations (Abildgaard *et al*. 1986).

The estimation of total biomass involved computing the biomass of each stream and aggregating the results for several creeks. The total biomass of fish in each creek was estimated by dividing the standardized average catch rate per creek with the area swept by the trawl during the standard haul operation, multiplying with the catchability coefficient of the trawl and the area of the creek survey.

$$B(c) = C(s)/(T \times q) \times a(s)$$

Where:

- B(c) = fish biomass of a creek,
- T = area swept during the standard haul operation,
- q = catchability coefficient and
- a(s) = surface area of a surveyed creek.

Results

Fish sampling efforts

The fish capture study involved 583 trawl tow sample stations in different creeks from June 2013 to May 2014. The study was influenced by high and low tides, seasonal variations and the flora in the creeks, primarily mangroves. The sections of the streams where fishing is permitted were covered by nearly all of the sample sites. Little inlets of water that are only accessible by small boats are known as creeks. Local fishermen use traditional fishing techniques and small wooden boats. Modified small boat known as the "dolphin" was utilised for this survey. All of the streams were routinely sampled, with the exception of Khar and Khajar creeks, where only June and September 2013 sampling was done due to the creeks' turbulence and powerful sea currents. Fish samples were taken for this study from 13 streams that had a total of 583 sampling points. The trawl net was used to gather the fish samples. The location of mangroves in the creeks, seasonality and tidal levels all influence these sample locations. Out of the total 632 planned stations, 588 were deemed legitimate tows; of these, 46% were bottom trawls and 54% were pelagic trawls in various streams. Fig. 2A shows an uneven distribution of hauls carried out in several streams, with a notable shortage of tows. This is because to the stream mouth's high tides and powerful sea currents. With the exception of the Khar and Khajar Creeks, every watercourse was routinely tested. Fig. 2B displays the percentage distribution of samples for both pelagic and demersal trawling in the streams. Fig. 2C shows the research area's monthly distribution of trawl sample by gear. Fig. 2D shows monthly distribution of trawl sampling in different creeks.

Month wise catch analysis

Seasonal variations in creeks can affect fish capture, with summers being pleasant and winters slightly below freezing. The study period was divided into three categories: pre-monsoon, post-monsoon and monsoon. Monthly catch frequencies were checked to identify fluctuations in fish populations. Various peaks were identified (Fig. 3A), including a peak in June (51.2 kg/h) due to the close season for fishing during June and July, resulting in a high catch rate per unit of effort (Fig. 3B). The September pike, weighing 66.81 kg per hour, was linked to highland precipitation due to intense rainstorms carrying silt and cultivators downhill to the River Indus and its tributaries. Fish production rose due to the dilution of stream water caused by the combination of freshwater and saltwater. The maximum number of benthic fish caught in July was 50.0 kg/h. However, fish catches in August decreased after a sharp reduction in June and July.

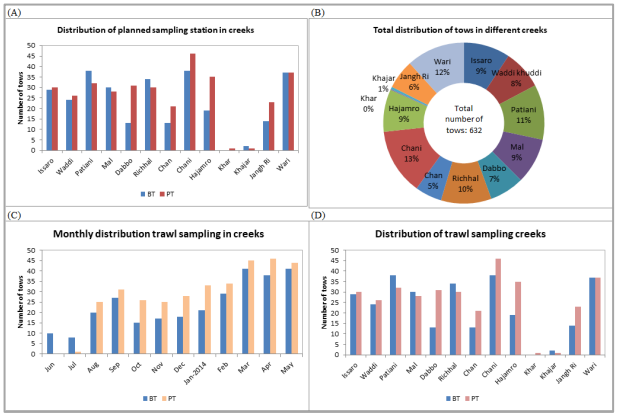

Fig. 2: (**A**) Distribution of trawl sampling in different creeks; (**B**) Total distribution of tows in percentage in different creeks; (**C**) Monthly distribution of trawl sampling and (**D**) Monthly distribution of trawl sampling in different creeks

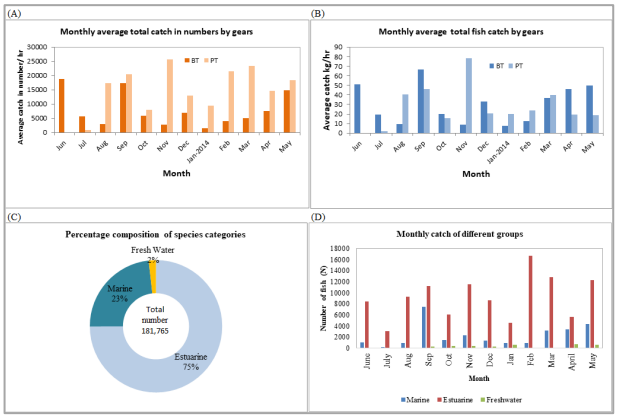

Fig. 3: (**A**) Monthly average total fish catch (in numbers) by gears; (**B**) Monthly average total fish catch (in kg) by gears; (**C**) Percentage composition of species by categories and (D) Monthly catch of different categories

Qualitative and Quantitative Analysis

Fish grouping by habitat

Stream environments are the permanent home of estuarine animals including sardines, anchovies and crabs. In contrast, marine fish are not permanent inhabitants of the stream environment; instead, they occasionally migrate to the open ocean for juvenile and spawning stages. The stability of ecosystems depends on freshwater fish, which are only caught during certain seasons and in streams with greater freshwater supplies. This is especially true for estuarine fish species' breeding habitats. The accidental introduction of river water into these streams emphasises how crucial freshwater is to stream ecosystems. Details of the 241 distinct fish species collected are shown in Table 2A to 2H.

A total of 181,765 fish were captured (Fig. 3C), consequently, 75% of fish in a particular year were found in estuaries, 23% in marine environments and 2% in freshwater environments. It is evident that estuarine species capture rates are generally higher due to the stream's ecosystem. In contrast to marine fish, which are distributed somewhat throughout the year, estuarine fish are widely distributed throughout the research region. Fish species group monthly distribution by habitat is displayed in Fig. 3D.

Fish abundance by habitat

The distribution of fish by habitat type in different streams is shown in Fig. 4A and Fig. 4B shows the relationship between physical attributes and fish species found in estuaries and marine waters. The diversity of freshwater fish species was not very high.

Abundance of cephalopods

The cephalopods are marine animals; the groups of cephalopods are depicted in Fig. 4C, where three primary groupings are seen: two are about squid, two are about cuttlefish and one is about octopuses. Among the species are *Uroteuthis duvauceli, Loligo* sp., *Octopus* sp., *Sepia latimanus, Sepiella inermis, Sepiella* sp. and Sepiidae. The distribution was dominated by squid, making up 58% of the total. *Sepeilla* sp. (20%), followed by *Uroteuthis duvaucelii* (18%), Sepeidae 3%) and Octopus 1%, respectively. The regional distribution of cephalopod species in several streams is depicted in Fig. 4D. Patiani and Mal, two of the most abundant streams, each have six species, whereas Richhal and Issaro each have five species. Each of the creeks Dabbo and Wari contains three species, while Waddi Khuddi and Chhan have four species each. There are two species in each of the Chani, Hajamro and Khajar creeks and only one in Khajar Creek. However, the Khar Creek and Jangh Rivers are devoid of cephalopod species.

Abundance of crabs

There are 16 species or species groups of crabs in the study area; nine of the more prominent species or species groups are displayed in Fig. 5A. *Matuta planipes* had the highest frequency at 43%, the next highest percentages are (17%) for *Charybdis ferriata*, (14%), for *Portunus* sp. and Portunidae share 7% each, 4% for *Charybdis (Charybdis) calianasa* and *Portunus pelagicus* and 3% for *Charybdis (Charybdis) natator*. Fig. 5B displays the geographic spread of crab species in different streams. The most diversity of species appears to have been found at Patiani Creek, with eleven species or groups of species, followed by the streams Mal and Issaro with nine. Waddi Khuddi, Dabbo and Chann streams have eight species; Wari creeks and Jhang River have seven; there are six in Chani Creek and five in Richhal Creek. Hajamro Creek contains four different species of crabs, but Khajar Creek only has one. However, no kind of crab has been discovered at Khar Creek.

Table 2A: List of Cephalopod species collected from the Indus creek system

Sr. No.	Family/Species name, group name	FAO English name	Synonymized name
	CEPHALOPODS		
	SEPIIDAE		
1	*Sepiella inermis*	Spineless cuttlefish	
2	*Sepia latimanus*	Broadclub cuttlefish	
3	*Sepiella* sp.	Spineless cuttlefish	
4	Sepiidae	Cuttlefish	
	LOLIGINIDAE		
	loliginidae	Squid	
5	*Loligo* sp.	Squid	
6	*Uroteuthis duvauceli*	Indian squid	
	OCTOPODIDAE		
7	*Octopus* sp.	Octopus	

Table 2B: List of crab and lobster species collected from the Indus creek system

Sr. No.	Family/Species name, group name	FAO English name	Synonymized name
	CRABS		
	PORTUNIDAE		
1	*Charybdis (Charybdis) amboinensis*	Crab	
2	*Charybdis (Charybdis) annulata*	Banded-legged swimming Crab	*Charybdis annulata*
3	*Charybdis (Charybdis) callianassa*	Crab	*Charybdis callianassa*
4	*Charybdis (Charybdis) natator*	Ridged swimming crab	*Charybdis natator*
5	*Charybdis* sp.	Swimming Crab	
6	*Charybdis ferriata*	Swimming Crab	
7	*Portunus pelagicus*	Blue swimming crab	
8	Portunidae	Crab	
9	*Portunus* sp.	Swimming crab	
10	*Portunus sanguinolentus*	Three spot swimming crab	
11	*Scylla serrata*	Giant mud crab	
	CALAPPIDAE		
12	*Calappa pustulosa*	Box crab	
	DORIPPIDAE		
13	Dorippidae	Spider Crab	
	GRAPSIDAE		
14	*Metapograpsus* sp.	Purple climber crab	
	MATUTIDAE		
15	*Matuta planipes*	Moon crab	*Mutata planipes*
16	*Matuta* sp.	Moon crab	
	LOBSTERS		
	PALINURIDAE		
17	Palinuridae	Spiny lobster	

Table 2C: List of Penaeid shrimp collected from the Indus creek system

Sr. No	Family/Species name, group name	FAO English name	Synonymized name
	PENAEID SHRIMP PENAEIDAE		
A	Jaira shrimp		
1	*Penaeus semisulcatus*	Green tiger prawn	
2	*Penaeus monodon*	Giant tiger prawn	
3	*Penaeus indicus*	Indian white prawn	
4	*Penaeus canaliculatus*	Witch prawn	
5	*Penaeus japonicus*	Kuruma prawn	
6	*Penaeus merguiensis*	Banana prawn	
7	*Penaeus penicillatus*	Redtail prawn	
8	*Penaeus brevirostris*	Crystal Shrimp	
B	Kalri shrimp		
9	*Metapenaeus affinis*	Jinga shrimp	
10	*Metapenaeus stebbingi*	Peregrine shrimp	
11	*Metapenaeus brevicornis*	Yellow shrimp	
12	*Metapenaeus monoceros*	Brown shrimp	
C	Kiddi shrimp		
13	*Mierspenaeopsis sculptilis*	Rainbow shrimp	*Parapenaeopsis sculptitis*
14	*Metapenaeopsis stridulans*	Fiddler shrimp	
15	*Mierspenaeopsis hardwickii*	Spear shrimp	*Parapenaeopsis hardwickii*
16	*Parapenaeopsis stylifera*	Kiddi shrimp	
17	*Parapenaeopsis sp.*	Kiddi shrimp	
18	*Parapenaeopsis stylifera*	Coromandel shrimp	*Parapenaeopsis coromandelica*
19	*Parapenaeus longipes*	Flamingo shrimp	
20	Penaeidae	Shrimp	

Abundance of penaeid shrimps

Penaeid prawns fall into three commercial categories: Jaira, Kalri and Kiddi. Among the eight species (*Penaeus canaliculatus, P. monodon, P. japonicus, P. semisulcatus* and *Metapenaeus brevirostris*), *Penaeus indicus* predominated that were documented within the Jaira group. The second group of shrimp are called Kalri, or medium-sized shrimp. There are four species in this group, with *Metapenaeus stebbingi* being the most frequent. The other species are *M. affinis, M. Monoceros* and *M. brevicornis*. The smallest group of prawns, called "kiddi" prawns, consists of eight species. This group include *Mierspenaeopsis hardwickii, M. sculptilis, Penaeidae, Metapeneopsis stridulans, Parapenopsis coromandelica, Pp. stylifera* and *Pp.* sp. The dominant species was *Parapenaeus longiceps*. Fig. 5C displays the predominant Penaeid prawn species, which have hundred numbers, whereas, the geographical distribution of Penaeid prawns is shown in Fig. 5D. In Patiani Creek, there are thirteen species of Penaeid prawns, which seems to be more than the eleven species in Chani Creek and the ten species in Rachhal Creek. There are nine species in the streams of Mal, Jangh River and Wari, while there are eight in Waddi Khuddi. Issaro has seven species, Khajar Creek has six, Dabbo and Hajamro Creeks have five, Chann Creek has three and Khar Creek has just two.

Abundance of other shrimp excluding penaeid

The other shrimp include deep sea (*Solenocera* sp.) shrimp, carid shrimp, freshwater shrimp and Mantis shrimp. Fig. 6A demonstrates that 95% of the group in this category consisted of carid prawns, the mantis shrimp at 1%, deep sea shrimp at 0.1% and freshwater shrimp at 4%. The geographical distribution of other shrimp species excluding Penaeid shrimp) is shown in Fig. 6B. The study region appears to be well distributed with carid shrimp, the exception being Khar Creek. The deep-sea prawn, *Solenocera* sp., was found only in the Patiani and Wari creeks. Squilla and mantis shrimp are not widely distributed in the study region.

Table 2D: List of shrimp species excluding Penaeid shrimp collected from the Indus creek system

Sr. No	Family/Species name, group name	FAO English name	Synonymized name
	CARID SHRIMP ALPHEIDAE		
1	Alpheidae	Caridean shrimp	
	CARIDEA		
2	*Caridae* sp.	Caridean shrimp	*Caridae white*
3	Caridea	Caridean shrimp	
	LYSMATIDAE		
4	*Exhippolysmata ensirostris*	Hunter shrimp	
	HIPPOLYTIDAE		
5	Hippolytidae	Cleaner shrimp	
	THORIDAE		
6	Lebbeus sp.	Caridean deep sea shrimp	*Caridae white*
	SERGESTIDAE		
7	Sergestidae	Mesopelagic shrimp	
8	*Sergestes* sp.	Mesopelagic shrimp	
	DEEP SEA SHRIMP SOLENOCERIDAE		
9	*Solenocera choprai*	Ridgeback shrimp	
10	*Solenocera crassicornis*	Coastal mud shrimp	
11	*Solenocera* sp.	Solenocerid shrimps	
	FRESHWATER PRAWNS PALAEMONIDAE		
12	*Macrobrachium malcolmsonii*	Freahwater prawn	
13	*Macrobrachium rude*	River prawn	
14	*Nematopalaemon hastatus*	Estuarine prawn	
15	*Nematopalaemon tenuipes*	Spider prawn	
16	*Palaemon styliferus*	shrimp	
	MANTIS SHRIMP SQUILLIDAE		
17	*Harpiosquilla harpax*	Mantis shrimp	
18	*Harpiosquilla* sp.	Mantis shrimp	
19	*Oratosquilla* sp.	Mantis shrimp	
20	*Squilla* sp.	Mantis shrimp	
21	Squillidae	Mantis shrimp	

Abundance of large pelagic fish species
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The species composition of the large pelagic fish species group is shown in Fig. 6C. *Scomberoides commersonnianus* contributed 61%, followed by *Sphyraena* sp. (27%), *S. obtusata* (6%), *S. jello* (4%) and *Scomberoides* sp. 2%. These species are often classified as large pelagic species, similar to tuna. Fig. 6D shows the geographical distribution of large pelagic fish species. The most abundant streams in the research area include Dabbo, Richhal, Chann and Wari creeks (three species each), as well as Patiani and Mal creeks (four species each). There are two species in each of the streams Issaro, Waddi Khuddi and Hajamro, while there is only one species in the Jangh River and Chani creeks. There is no significant large pelagic fish catches in the Khajar and Khar streams.

Abundance of small pelagic fish species

The percentage composition of the families in the small pelagic fish group is shown in Fig. 7A. With 39% of the total, the Clupeidae family is the most prominent, followed by the Engraulidae (20%), Mugilidae (19%), jellyfish (10%), Leiognathidae (9%), Pristigasteridae (1%) and Hemiramphidae (less than 1%). Fig. 7B displays the regional distribution of small pelagic fish species. Twenty-nine species in the Issaro Creek, whereas twenty-eight in the Hajamro Creek. Richhal Creek has twenty-six species, Wari Creek contains twenty-four and Chani Creek contains twenty-two. There are twenty-one species in the Patiani and Mal streams and twenty in the Dabbo and Jangh River rivers. In Waddi Khuddi, there are nineteen species, whereas Chann Creek contains fourteen. Each of the streams called Khajar and Kahr is home to four species.

Table 2E: List of freshwater fish species collected from the Indus creek system

Sr. No.	Family/Species name, group name	FAO English name	Synonymized name
	AMBASSIDAE		
1	*Ambassis sp.*	Glassfish	
2	*Chanda nama*	Elongate glass-perchlet	*Chand nama*
3	*Parambassis ranga*	Indian glassy fish	*Parambasi ranga*
	ARIIDAE		
4	*Osteogeneiosus militaris*	Soldier catfish	*Osteogeneiosus miliataris*
	CLUPEIDAE		
5	*Gudusia chapra*	Indian river shad	
	CYPRINIDAE		
6	*Osteobrama cotio*	Cotio	*Orteobrama cotio*
7	*Pethio ticto*	Ticto barb	
8	*Puntius sophor*	Pool barbfish	
9	*Salmostoma bacaila*	Large razorbelly minnow	*Salmophoria bacaila*
	MASTACEMBELIDAE		
10	*Mastcembelus armatus*	Spiny eel	

Table 2F: List of large pelagic fish species collected from the Indus creek system

Sr. No.	Family/Species name, group name	FAO English name	Synonymized name
	CARANGIDAE		
1	*Scomberoides commersonianus*	Largemouth queen fish	
2	*Scomberoides* sp.	Leatherjacket	
	SPHYRAENIDAE		
3	*Sphyraena obtusata*	Obtuse barracuda	
4	*Sphyraena jello*	Pick handle barracuda	
5	*Sphyraena* sp.	barracuda	
	SCOMBRIDAE		
6	*Scomber* sp.	Mackerels	
7	*Scomberomorus* sp.	mackerels	
8	*Scomberomorus commerson*	Narrow-barred Spanish mackerel	
9	*Scomberomorus guttatus*	Indo-Pacific king mackerel	

Abundance of demersal fishes

With 110 species or species groups, the category of demersal fish is the largest group of finfish and is divided into two divisions. Species or subspecies that have more than 100 specimens are included in the first section (Fig. 7C). With 54% of the total, the Sciaenidae family has a prominent position. The Haemulidae, Ariidae,

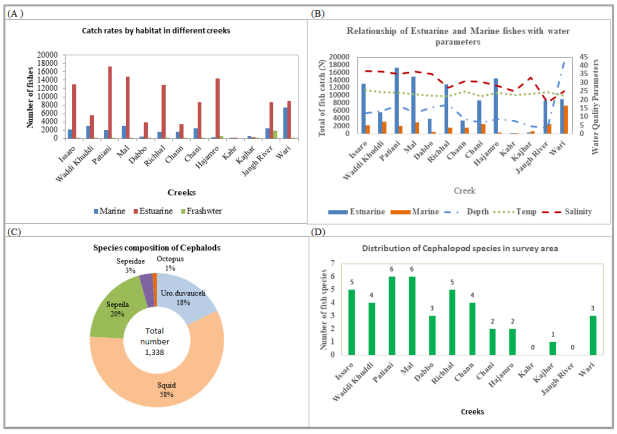

Fig. 4: (**A**) Catches by habitat in different creeks, (**B**) Relationship of estuarine and marine fishes with physical water parameters in different creeks; (**C**) Species composition of Cephalopods and (**D**) Geographical distribution of cephalopods in study region

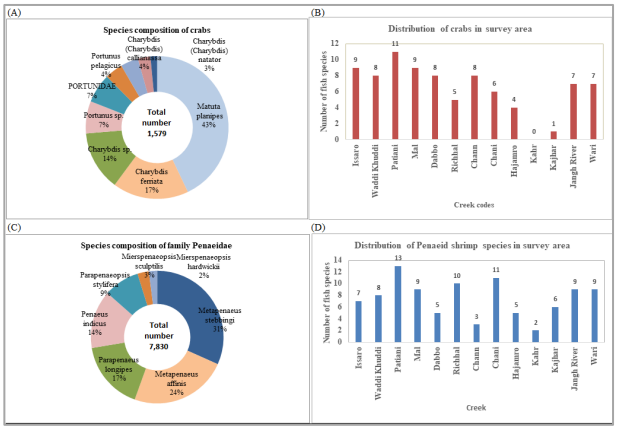

Fig. 5: (**A**) Species composition of crabs; (**B**) Geographical distribution of crabs in different creeks; (**C**) Species composition of family Penaeidae and (**D**) Geographical distribution of family Penaeidae

Platycephalidae, Carangidae, Siliginidae, Gerreidae and Cynoglossidae are next with 17%, 9% and 8%, respectively and 1% for the Trichiuridae, Gobiidae, Soleidae and Sparidae, respectively. The remaining species, as shown in Fig. 7D, are those for which less than 100 specimens were recorded. Terapontidae and Stromateidae were the top two families, each with sixteen percent; Callionymidae came in second, with 15%; Synanceillidae had a 12% share. 10% of them were Polynemidae. Drepaneidae was at 7%; Paralichthyidae and Lutjanidae each accounted for 5%; Schilbeidae and Tetraodontidae each accounted for 4%; Scatophagidae and Monocanthidae each had a 3% share.

Fig. 8A depicts the geographical distribution of demersal fish species. With 53 species, Waddi Khuddi Creek seems to be the most prolific, followed by Patiani Creek with 47 species. Forty species are found in Issaro Creek and forty in Wari Creek. Thirty-six species are found

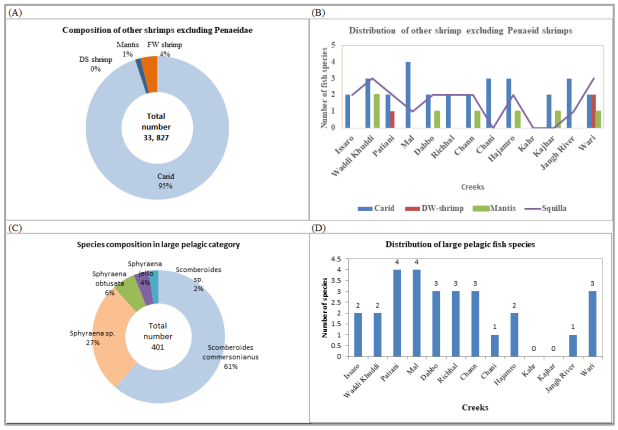

Fig. 6: (**A**) Composition of other shrimp excluding Penaeid shrimp; (**B**) Spatial distribution of other shrimp excluding Penaeid shrimps; (**C**) Species composition of large pelagic species category and (**D**) Geographical distribution of large pelagic species

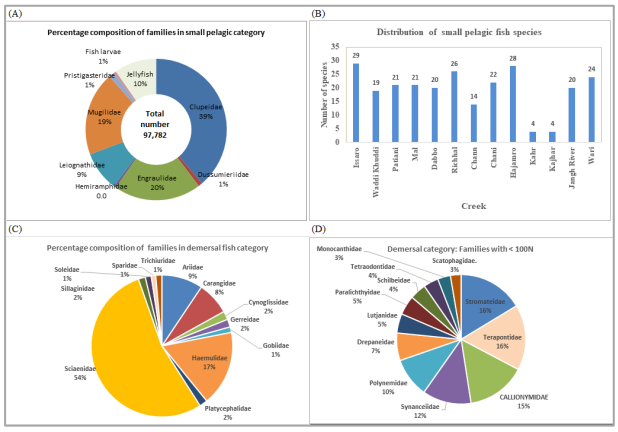

Fig. 7: (**A**) Species composition of small pelagic fish species category, (**B**) Geographical distribution of small pelagic species in the study area; (**C**) Percentage composition of families in demersal fish category and (**D**) Percentage composition of families with < 100N in demersal fish category

in Richhal Creek and thirty-eight in Mal Creek. Dabbo Creek has twenty-nine species, Chani Creek has twenty-eight, Jangh River has twenty-six, Kajhar Creek has eleven and Kahr Creek has just one. The spatial distribution of freshwater fish and prawns in the research area is shown in Fig. 8B. *Salmostoma bacaila* made up 14% of the group of freshwater fish, whereas *Gudusia chapra* made up 82%.

Index of Abundance and Biomass Estimation

Index of abundance

The average catch rate (kg/h tow) for the different streams that were studied is shown in Table 3. There appear to be significant differences depending on the season and the creek. Wari Creek has the greatest average catch rate, while Dabbo Creek has the lowest, ranging from 2.61 to 8.57 kg/h tow.

Table 2G: List of small pelagic fish species collected from the Indus creek system

Sr. No.	Family/Species name, group name	FAO English name	Synonymized name
	BELONIDAE		
1	*Strongylura strongylura*	Spottail needlefish	
	CLUPEIDAE		
2	*Anodontostoma chacunda*	Chacunda gizzard shad	
	Clupeidae	Shad, sardine	
3	*Escualosa thoracata*	White sardine	
4	*Hilsa kelee*	Kelee shad	
5	*Nematalosa nasus*	Bloch's gizzard shad	
6	*Sardinella* sp.	Sardine	
	DUSSUMIERIIDAE		
7	*Dussumieria acuta*	Rainbow sardine	
8	*Dussumieria elopsoides*	Slender rainbow sardine	
	ELOPIDAE		
9	*Elops machnata*	Tenpounder	
	ENGRAULIDIDAE		
10	*Coilia dussumieri*	Goldspotted grenadier anchovy	
11	Engraulididae	Anchovies	
12	*Stolephorus indicus*	Indian anchovy	
13	*Stolephorus* sp.	Anchovy	
14	*Thryssa dussumieri*	Dussumier's thryssa	
15	*Thryssa hamiltonii*	Hamilton's thryssa	
16	*Thryssa mystax*	Moustached thryssa	
17	*Thryssa* sp.	Anchovies-thryssa	
18	*Thryssa vitrirostris*	Orangemouth anchovy	
	HEMIRAMPHIDAE		
19	*Hemiramphus* sp.	Halfbeaks	
20	*Hyporhamphus dussumieri*	Dussumier's halfbeak	Hyporhamphus dussemeri
21	*Hyporhamphus limbatus*	Congaturi halfbeak	
22	*Hyporhamphus* sp.	halfbeaks	
	LEIOGNATHIDAE		
23	*Equulites lineolatus*	Ornate ponyfish	Leiognathus lineolatus
24	*Eubleekeria splendens*	Splendid ponyfish	Leiognathus splendens
25	*Karalla dussumieri*	Dussumier's ponyfish	Leiognathus dussumieri
26	*Leiognathus berbis*	Berber ponyfish	
27	*Leiognathus brevirostris*	Shortnose ponyfish	
28	*Leiognathus equula*	Common ponyfish	Leiognathus equulus
29	*Leiognathus* sp.	Ponyfish	
30	*Nuchequula blochii*	Twoblotch ponyfish	
31	*Photopectoralis bindus*	Orangefin ponyfish	Leiognathus bindus
32	*Secutor insidiator*	Slenderbarred ponyfish	
	MUGILIDAE		
33	*Liza carinata*	Keeled mullet	
34	*Liza* sp.	Mullet	
35	*Mugil sp.*	Mullet	
36	Mugilidae	Mullet	
37	*Osteomugil cunnesius*	Longarm mullet	*Valamugli cunnesius*
38	*Planiliza abu*	Abu mullet	*Liza abu*
39	*Planiliza macrolepis*	Largescale mullet	*Liza macrolepis*
40	*Planiliza subviridis*	Greenback mullet	*Liza subviridis*
	PRISTIGASTERIDAE		
41	*Ilisha elongata*	Elongate ilisha	
42	*Ilisha megaloptera*	Bigeye ilisha	
43	*Ilisha* sp.	Ilisha	

Table 2G: Continued

Table 2G: Continued

44	*Pellona ditchela*	Indian pellona
	SCOMBRIDAE	
45	Rastrelliger kanagurta	Indian mackerel
	Fish larvae	
46	Fish larvae	
	Cnidaria	
47	Jellyfish	

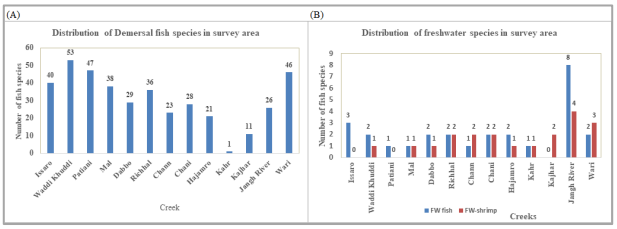

Fig. 8: (**A**) Geographical distribution of demersal fish species and (**B**) Geographical distribution of freshwater fish species

The term "σ" refers to the standard deviation, which measures how widely distributed the data are in relation to the mean. Specifically, data that have a small or low standard deviation are centred on the mean, whereas data that have a large or great standard deviation are distributed widely. The Jhang River capture rates had the lowest standard deviation of 1.68, with a minimum value of 0.02 and a maximum value of 45.24; the Chann Creek catch rates had the highest value of 14.24.

If the distribution of a variable leans more to the left or right, it is said to be skewed. A measure of this symmetry is called skewness. In contrast to negative skewness, which indicates larger values, positive skewness indicates lower values. A skewness score between -1 and +1 is preferable, although generally speaking, a value between -2 and +2 is acceptable. Skewedness ranges from -0.26 to 2.97, with the Jhang River having the lowest value and Hajamro Creek having the highest value. At Richhal (2.67), Mal (2.40), Hajamro (2.97), Chann (2.51) and Waddi Khuddi (2.28), the skewness values showed a considerable departure from normality.

Kurtosis indicates how too peaked or flat the distribution is in relation to a normal distribution. A distribution with positive kurtosis is more peaked than one with negative kurtosis. A kurtosis more than +2 indicates an overly peaked distribution, whereas a kurtosis smaller than -2 indicates an overly flat distribution. Between -1.82 and 9.01 is Kurtosis's value; Patiani Creek has the lowest value and Hajamro Creek has the greatest value. Kurtosis values greater than +2 were found for Richhal, Mal, Hajamro, Chann, Dabbo and Wadi Khuddi, suggesting an excessive peak variation in the distribution. The average catch rate for each stream, along with a 95% confidence interval, is also shown in Table 3.

Table 2H: List of demersal fish species collected from the Indus creek system

Sr. No.	Family/Species name, group name	FAO English name	Synonymized name
	Rays/Skates DASYATIDAE		
1	*Himantura walga*	Scaly whipray	
	Sharks		
	TRIAKIDAE		
2	*Mustelus* sp.	Smooth-hounds shark	
	Demersal fishes		
	APOGONIDAE		
3	*Apogon quadrifasciatus*	Broadbanded cardinalfish	
	ARIIDAE		
4	*Arius maculatus*	Spotted catfish	
5	*Arius* sp.	Seacatfish	
6	*Netuma thalassina*	Giant catfish	*Arius thalassinus*
7	*Plicofollis dussumieri*	Blacktip sea catfish	*Arius dussumieri*
8	*Plicofollis layardi*	Thinspine sea catfish	*Arius tenspinis*
	CALLIONYMIDAE		
9	Callionymidae	Dragonets	
10	*Callionymus* sp.	Dragonets	
	CARANGIDAE		
11	*Alectis indica*	Indian threadfish	
12	*Alepes djedaba*	Shrimp scad	
13	*Alepes kleinii*	Razorbelly scad	
14	*Alepes kleinii*	Razorbelly scad	Caranx para
15	*Alepes* sp.	Scad	
16	*Atropus atropos*	Cleftbelly trevally	
17	Carangidae	Jacks, scad	
18	*Carangoides* sp.	Jacks, scad	
19	*Caranx* sp.	Trevallies	
20	*Parastromateus niger*	Black pomfret	
21	*Trachinotus mookalee*	Indian pompano	
22	*Trachinotus* sp.	Pompano	
23	*Uraspis sp.*	Jacks, scad	
	CYNOGLISSIDAE		
24	*Cynoglossoides* sp.	Solefish	
25	*Cynoglossus arel*	Largescale tonguesole	
26	*Cynoglossus puncticeps*	Speckled tonguesole	
27	*Cynoglossus* sp.	Solefish	
28	*Paraplagusia bilineata*	Doublelined tonguesole	
	DREPANEIDAE		
29	*Drepane longimana*	Concertina fish	
30	*Drepane punctata*	Spotted sicklefish	
31	*Drepane* sp.	Sicklefishes	
	GERREIDAE		
32	*Gerres filamentosus*	Whipfin silver-biddy	
33	*Gerres limbatus*	Saddleback silver-biddy	*Gerres lucidus*
34	*Gerres longirostris*	Strongspine silver-biddy	*Gerres poiete*
35	*Gerres* sp.	silver-belly	
	GOBIIDAE		
36	*Boleophthalmus dussumieri*	Mudskipper	
37	*Glossogobius giuris*	Tank goby	
38	Gobiidae	Goby	
39	*Gobioides* sp.	Goby	
40	*Gobius* sp.	Goby	
41	*Parachaeturichthys ocellatus*	Bobies	
42	*Trypauchen vagina*	Burrowing goby	
	HAEMULIDAE		
43	*Pomadasys kaakan*	Javelin grunter	
44	*Pomadasys maculatus*	Saddle grunt	
45	*Pomadasys stridens*	Striped piggy	
	LUTJANIDAE		
46	*Lutjanus johnii*	John's snapper	
47	*Lutjanus* sp.	Snapper	
	MONOCANTHIDAE		
48	Monacanthidae	Filefish	
49	*Monacanthus* sp.	Filefish	
	MURAENESOCIDAE		
50	*Muraenesox cinereus*	Daggertooth pike conger	
	OPHICHTHIDAE		
51	Ophichthidae	Snake Eel	
52	*Pisodonophis cancrivorus*	Longfin snake-eel	
	PARALICHTHYIDAE		
53	*Pseudorhombus arsius*	Lefteye flounders	
54	*Pseudorhombus elevatus*	Deep flounde	
55	*Pseudorhombus* sp.	Flounder	
	PLATYCEPHALIDAE		
56	*Cociella crocodila*	Crocodile flathead	
57	*Grammoplites scaber*	Rough flathead	
58	*Grammoplites suppositus*	Spotfin flathead	
59	*Platycephalus indicus*	Bartail flathead	
60	*Platycephalus* sp.	Flatheads	
61	*Sorsogona* sp.	Flatheads	
	PLOTOSIDAE		
62	*Plotosus lineatus*	Striped eel catfish	
	POLYNEMIDAE		
63	*Eleutheronema tetradactylum*	Fourfinger threadfin	
64	*Filimanus heptadactyla*	Sevenfinger threadfin	*Polynemus heptadactylus*
65	*Polynemus* sp.	Threadfins	
	SCATOPHAGIDAE		
66	*Scatophagus argus*	Spotted scat	
	SCHILBEIDAE		
67	*Clupisoma garua*	catfish	
	SCIAENIDAE		
68	*Johnius belangerii*	Belanger's croaker	
69	*Johnius borneensis*	Sharpnose hammer croaker	*Johnieops vogleri*
70	*Johnius carouna*	Caroun croaker	
71	*Johnius dussumieri*	Sin croaker	*Johnieops sina*
72	*Johnius dussumieri*	Sin croaker	
73	*Johnius elongatus*	Spindle croaker	
74	*Johnius macrorhynus*	Big-snout croaker	*Johnieops macrorhynus*
75	*Johnius* sp.	croaker	
76	*Otolithes cuvieri*	Lesser tigertooth croaker	
77	*Otolithes ruber*	Tigertooth croaker	
78	*Otolithoides biauritus*	Bronze croaker	
79	*Pennahia anea*	Grayfin jewfish	
80	*Pennahia* sp.	Croaker	
81	*Sciaena* sp.	Black drums	
82	Sciaenidae	Croakers, drums	
83	*Daysciaena albida*	Bengal corvina	*Nibea albida*
	SERRANIDAE		
84	*Epinephelus diacanthus*	Spinycheek grouper	
85	*Epinephelus* sp.	Grouper	
86	*Epinephelus stoliczkae*	Epaulet grouper	
	SILLAGINIDAE		
87	*Sillago sihama*	Silver sillago	
88	*Sillago* sp.	Ladyfish	
	SISORIDAE		
89	*Bagarius bagarius*	Goonch	
	SOLEIDAE		
90	*Brachirus orientalis*	Oriental sole	
91	*Solea elongata*	Elongate sole	
	SPARIDAE		
92	*Acanthopagrus berda*	Goldsilk seabream	
93	*Acanthopagrus latus*	Yellowfin seabream	
94	*Rhabdosargus niger*	Blackish stumpnose	*Rhobhosargus niger*
95	*Rhabdosargus sarba*	Goldlined seabream	
96	*Sparidentex hasta*	Sobaity seabream	*Sparidenter hasta*
	STROMATEIDAE		
97	*Pampus argenteus*	Silver pomfret	
	SYNANCEIIDAE		
98	*Pseudosynanceia melanostigma*	Blackfin stonefish	

Table 2H: Continued

Table 2H: Continued

Table 2H: Continued

99	*Pseudosynanceia melanostigma* SYNGNATHIDAE	Blackfin stonefish	*Pseudosynanceia stigmametano*
100	Syngnathidae SYNODONTIDAE	Pipefishes	
101	*Harpadon nehereus* TERAPONTIDAE	Bombay duck	
102	*Terapon jarbua* TETRAODONTIDAE	Jarbua terapon	
103	*Lagocephalus sp.*	pufferfish	
104	*Lagocephalus spadiceus*	Half-smooth golden pufferfish	
105	*Chelonodon patoca* TRIACANTHIDAE	Puffers fish	
106	*Pseudotriacanthus strigilifer*	Long-spined tripodfish	
107	Triacanthidae TRICHIURIDAE	Tripodfishes	
108	*Lepturacanthus savala*	Savalai hairtail	
109	*Lepturacanthus* sp.	Ribbonfish	
110	*Trichiurus lepturus*	Largehead hairtail	

Fish biomass estimation in Indus creeks

This study attempts to use the swept area technique to calculate the biomass of fish resource in the streams under investigation and the result is extended to the full 3,850 sq. km. zone. Table 4 displays estimates of fish biomass for a different creek that were studied. Since the data sample for Khar and Khajar Creeks were less than three, a different approach was taken. Based on the average biomass of the observed region, the result was extrapolated by multiplying it by the total area of these creeks. After the projected biomass of each stream under study was extended to the whole area of mangroves and creeks, 9,594 MT were produced.

Discussion

The creek survey examined the biological resources of marine fisheries in the various creek regions. These areas serve as the breeding and nesting grounds for fish, crustaceans and other marine life. Assessing the biological importance of stream regions for marine fisheries is the main goal of this study, taking into account their contribution, migration patterns and seasonality variation. Additionally, the study will identify potential threats to the fishery in these areas and provide recommendations to safeguard Pakistan's fish resources. Table 1 lists the total area, distance from the sea, survey length, survey percentage and number of stations in each selected stream. Fig. 1A shows sample locations in selected creek. Fish samples from 13 streams with a total of 583 sampling locations were collected for this investigation. The samples of fish were collected using the bottom and pelagic trawl nets. Fig. 2A shows an uneven haul distribution with a pronounced tow deficit in numerous streams. This is due to the strong sea currents and high tides at the stream mouth. Every watercourse was regularly tested, save for the Khar and Khajar Creeks. The percentage distribution of samples from both pelagic and demersal trawling in the streams is shown in Fig. 2B. The monthly distribution of the trawl sample by gear in the research region is displayed in Fig. 2C. The monthly distribution of trawl sample in several streams is displayed in Fig. 2D.

The number of fish captured is significantly impacted by the seasonal fluctuations that the streams are prone to. The research region features three distinct climatic seasons and a maritime environment with warm summers and mild winters. There are three seasons: the rainy season (June to August), September through December is the post-rainy season, while January through May is the pre-rainy season. The catch rates in numbers had many maxima (Fig. 3A). The first occurs in June when fewer local fishermen were in the creeks as a result of the Sindh Government's fishing prohibition, which raised the capture per unit effort during this study. However, after June and July, there was a discernible drop in fish captures in August, followed by a rise in September. This is because the freshwater Indus River and its tributaries receive sediment and nutrients from rainfall that occurs upstream during the monsoon. Thus, salinity, temperature and stream water dilution are all balanced by strong ocean currents and freshwater flows, all of which increase fish production. The pelagic trawl net capture rates show similar patterns, with the exception of November, when the highest jellyfish catch rates are seen.

After the peak in September, there was a gradual decline in fish collection from October through November and January. First, fish species shift because to higher-than-normal salinity levels throughout these months. Second, given the high capture rates in the months prior, overfishing may have happened during these months. The catch rates increase again from February to May; this might be because certain fish species overwinter in the streams. This type of overwintering in prawn species is reported by Ahmed (1985) and Zalinge *et al*. (1986b, 1987). There is a noticeable variation in the number of fish captured kg/h each month (Fig. 3B). According to Fanning *et al*. (2016) fishing season begins in January and runs through April, then declines from May to July and peaks lean in June and July. Their findings were based on port clearance data collected by Pakistani customs officials. The fishing season resumes in August, peaks in September and then declines once more until December. This illustrates how, in contrast to fishing on open oceans, fishermen are confined to the streams region in June and July due to high winds and currents caused by the southwest monsoon.

Pakistan's fish fauna is diversified, much like the fish populations of other tropical countries around the world. Information on the taxonomy of marine fishes found in Karachi and along Sindh and Balochistan's coastlines was provided by Qureshi (1955). Jaleel and Khaliluddin (1972) prepared a checklist of marine species found in West Pakistan. Fish classified as true-bony (Teleostomi) and non-bony (Elasmobranchii) were the two parts that made up the section. That list includes around four hundred species of

Table 3: Monthly average fish catch (kg/h) in different creeks

Creeks Name	Chani	Issaro	Richhal	Mal	Hajamaro	Chann	Khar	Dabbo	Wari	Jhang River	Waddi Khuddi	Patiani	Khajar
Jun-13	1.57		36.58	5.98					7.00				0.08
Jul		1.73	0.72	15.50							1.46	2.40	
Aug	9.11	5.85	3.51	0.70	10.14	1.09		0.81	0.87	0.85	0.07	18.00	
Sep	7.04	3.22	7.41	30.69	2.35	0.05	1.14	2.93	22.02	3.69	25.61	2.60	4.20
Oct	3.97	11.97	1.07	0.64	2.52	45.24		0.02	6.04	4.27	2.94	2.25	
Nov	12.67	4.01	1.29	0.06	44.27	0.40		2.65	16.45	3.72	0.12	1.53	
Dec	1.65	5.60	11.07	2.41	4.44	0.02		1.30	1.33	3.21	7.53	15.53	
Jan-2014	1.20	7.71	2.86	0.27	3.21	0.18		0.56	4.91	4.16	1.26	0.58	
Feb	6.69	0.22	2.86	5.18	3.15	3.65		0.14	5.92	6.86	1.13	4.03	
Mar	4.13	6.64	11.37	3.71	1.48	2.56		9.32	15.10	4.81	8.35	5.76	
Apr	18.40	1.24	3.19	2.86	1.48	17.54		5.52	4.04	6.48	6.99	15.34	
May	9.07	4.65	7.56	3.66	3.36	5.12		2.85	10.55	4.09	6.68	16.05	
Total	75.50	52.83	89.49	71.66	76.40	75.84	1.14	26.10	94.23	42.14	62.14	84.07	4.28
Average	12.58	8.81	13.77	11.02	13.89	13.79	1.14	4.75	15.71	7.66	10.36	14.01	2.85
Standard Deviation	5.29	3.33	9.89	8.84	13.11	14.24	n.a	2.90	6.72	1.68	7.34	6.97	2.91
variance	27.99	11.12	97.90	78.08	171.85	202.90	n.a	8.40	45.11	2.82	53.84	48.52	8.49
Descriptive statistics	*Chani*	*Issaro*	*Richhal*	*Mal*	*Hajamaro*	*Chann*		*Dabbo*	*Wari*	*Jhang River*	*Waddi Khuddi*	*Patiani*	
Mean	6.86	4.80	7.46	5.97	7.64	7.58		2.61	8.57	4.21	5.65	7.64	
Standard Error	1.60	1.01	2.86	2.55	4.15	4.50		0.92	2.03	0.53	2.21	2.10	
Median	6.69	4.65	3.35	3.26	3.18	1.83		1.98	6.04	4.13	2.94	4.03	
Standard Deviation	5.29	3.33	9.89	8.84	13.11	14.24		2.90	6.72	1.68	7.34	6.97	
Sample Variance	27.99	11.12	97.90	78.08	171.85	202.90		8.40	45.11	2.82	53.84	48.52	
Kurtosis	0.88	0.91	7.91	5.94	9.01	6.45		2.50	-0.08	1.29	6.07	-1.82	
Skewness	1.02	0.74	2.67	2.40	2.97	2.51		1.58	0.89	-0.26	2.28	0.57	
Range	17.20	11.75	35.86	30.63	42.79	45.22		9.30	21.15	6.01	25.54	17.42	
Minimum	1.20	0.22	0.72	0.06	1.48	0.02		0.02	0.87	0.85	0.07	0.58	
Maximum	18.40	11.97	36.58	30.69	44.27	45.24		9.32	22.02	6.86	25.61	18.00	
Sum	75.50	52.83	89.49	71.66	76.40	75.84		26.10	94.23	42.14	62.14	84.07	
Count	11.00	11.00	12.00	12.00	10.00	10.00		10.00	11.00	10.00	11.00	11.00	
Confidence Level (95.0%)	3.55	2.24	6.29	5.61	9.38	10.19		2.07	4.51	1.20	4.93	4.68	
Minimum	3.31	2.56	1.17	0.36	-1.74	-2.61		0.54	4.05	3.01	0.72	2.96	
Maximum	10.42	7.04	13.74	11.59	17.02	17.77		4.68	13.08	5.41	10.58	12.32	

*The blank cell in each creek represents that survey was not conducted during this period

fish that have been reported to have been taken in the Arabian Sea off the coastlines of Sindh and Balochistan. The list was expanded in 1981 to include thirty-two more fish species (Jaleel and Khaliluddin 1981). Bianchi (1985) provided a valuable commercial description of 200 marine and brackish water species found in Pakistan, from 164 families, whereas, Hoda (1985) discovered around 370 genera and 760 species. A book about the maritime fisheries of Pakistan that are commercially significant includes information on 114 distinct species, including pelagic, demersal and tiny fish (Majid *et al*. 1992). The Field Guide to Fish Species of Pakistan was revised by Psomadakis *et al.* (2015) and now includes eight hundred species of finfish, molluscs, skates, prawns, lobsters, sharks and sea snakes. Fish species found in Khober Creek, which is next to Keti Bander, include eighty-four (Amir *et al*. 2016). During the creek survey carried out as part of the FRAP project, 243 species were found in the study region Table 2A to 2H. One hundred distinct species of fish have been identified in the Indus Delta mangroves (IUCN 2005).

Fish are divided into two primary classes: freshwater and marine. Other categories, such as coastal, shallow and open sea, are based on the maritime environment. Fish species are divided into three categories based on their environmental habitat: freshwater, marine and estuarine. Fish species in the open ocean are further separated into three categories: pelagic, mesopelagic and demersal (Fig. 1B). A total of 181,765 fish were captured (Fig. 3C). Consequently, 75% of fish in a particular year were found in estuaries, 23% in marine environments and 2% in freshwater environments. The Fig. 3D shows the monthly distribution of fish species by habitat group. Estuarine species were widely distributed in each month.

Fig. 4A shows the distribution of fish species by habitat groups in different creeks. It is clear that the ecology of the stream contributes to the typically greater catch rates of estuary species. Estuarine fish are broadly spread across the research zone, but marine fish are scattered slightly throughout the year. Fig. 4B shows the correlation between physical characteristics and fish species present in estuaries and marine waters. Environmental samples were collected using the CTD-Castway and the data were described in detail by Khan and Abbas (2020). Despite being extremely sensitive to temperature and salinity, juvenile prawns may survive in salinities as low as 12–16 ppt. Since their preferred temperature settings are around 28–31°C, beyond this acceptable temperature range can result in high mortality rates (ASEAN 1978). According to Khan and Abbas (2020),

Table 4: Estimation of fish Biomass in different creeks

Sr. No.	Creeks name	Area (sq. km)	No. of tows	Average kg/h	Density kg/sq.km	Biomass tons	Extrapolated biomass tons	Total biomass tons
1	Chani Creek	4.24	84	12.58	2962.65	12.56		
2	Issaro Creek	9.98	59	8.81	2073.14	20.69		
3	Richhal Creek	10.26	64	13.77	3241.49	33.26		
4	Mal Creek	14.90	58	11.02	2595.60	38.67		
5	Hajamaro Creek	15.24	54	13.89	3270.55	49.84		
6	Chann Creek	18.35	34	13.79	3246.45	59.57		
7	Khar Creek	27.61	1	1.14	268.40	-	56.22	
8	Dabbo Creek	30.06	44	4.75	1117.25	33.58		
9	Wari Creek	36.23	74	15.71	3697.65	133.97		
10	Jhang Creek	37.22	37	7.66	1803.87	67.14		
11	Waddi Khuddi Creek	49.02	50	10.36	2438.45	119.53		
12	Patiani Creek	57.68	70	14.01	3298.86	190.28		
13	Khajar Creek	89.65	2	2.85	671.78	-	182.53	
	Total survey area	400.44	631			759.10	238.75	998
	Av. biomass/ sq.km					2.04		2.49
	Total creek area sq.km	3850						9,594
Net width x height of net/ 2 π								
Net spread= (7.6x3.25)/(2*3.13) = 7.86								
q= 1								
distance 1.5 na.mi (or 1852 m) = 1852								
net spread/distance covered = 0.0042								
Total creek = 3850 sq.km (Brandhort 1986)								
Descriptive statistics								
Mean				76.77				
Standard Error				16.65				
Median				56.22				
Mode				#N/A				
Standard Deviation				60.02				
Sample Variance				3602.42				
Skewness				1.01				
Range				177.72				
Minimum				12.56				
Maximum				190.28				
Sum				998.07				
Count				13				
Confidence Level (95.0%)				36.27				

salinities between 10.7 and 41.1 ppt are the best range for a number of marine species to exist in the investigated location and water temperatures between 27.3 and 31.2ºC. These findings are consistent with those of ASEAN (1978). Surface upwelling on the Pakistani coast is believed to be caused by warmer water conditions, which are prevalent from October to April and are most visible between November and February (Hussain *et al*. 1970). This upwelling transports food and nutrients from the bottom to the surface for a variety of estuary fish species.

However, many fish species undergo changes and eventually disappear between November and February, when the oxygen supply totally vanishes. As a result, the dissolved oxygen levels of numerous benthic species fluctuate over the shelf areas between Karachi and Bombay (Banse 1984). Nonetheless, Khan and Abbas (2020) discovered that the study area had a discernible salinity throughout these months. The salinity levels of the Issaro, Waddi Khuddi, Dubbo, Mal and Patiani streams increased as they approached the shallow depths west of the Jhang River. Estuarial fish stocks have been hit harder by this than marine fish stocks, as marine species tend to be far more migratory and adjust to nearly any environment relatively quickly. It is summarized that estuarine species are vulnerable to dissolved oxygen depletion because of the rise in salinity that occurs at shallow depths as a result of warming. As a result, although superficial salinities in the Chan, Chani, Hajamro and Jhang River streams have not altered much, salinity declines with depth in these creeks. The primary reason for the apparent low salinity along the Jhang River and Hajamro Creek is the fresh water. The economically valuable species collected in the survey region, such as *Acanthopagrus arabicus* (Arabian yellowfin seabream), exhibit a similar trend. They feed in the mangroves during high tide and at low tide they return to the sea. Freshwater fish were also captured in the study region. Fishes of this type is appropriate for capturing during specified seasons and in creeks that have larger freshwater supplies than other streams. In fact, river water bring them into certain creeks was pure chance. This group is significant because it shows that freshwater exists in the creeks, which is necessary to keep the creek ecology in balance and is especially crucial for the estuarine fish population that will follow.

The group Cephalopod include octopus, squid, cuttlefish and nautilus, among other energetic, predatory soft-bodied invertebrates (Fig. 4C). To capture and cling to predators, they possess a minimum of eight tentacles that are fitted with suckers. With their pliable, thin inner shell, squid move like torpedoes at high speeds. Cuttlefish resemble squids in look and behaviour due to their stouter bodies and internal cuttlebone shell. Primarily found in deep water, octopuses have the ability to swim or walk on two of their eight limbs (Psomadakis *et al*. 2015; Kennedy *et al.* 2019). The quick development, high metabolic rates and exceptional phenotypic flexibility of cephalopods result in their short lifespans. Changes in the environment are frequently associated with annual variations in population counts. As food for people, prey and predators; cephalopods are essential to the ecology. During 2009–2015 fisheries resource survey, a wide variety of cephalopods were discovered (Fanning *et al.* 2016; Khan and Abbas 2024), albeit few individuals from each category were detected in the examination region. Since cephalopods are maritime species and require a marine habitat, the Khar Creek and Jhang Rivers are barren of cephalopod species (Fig. 4D).

In the study region, 16 different species (Table 2B) or species groups of crabs were identified, with two of them being economically significant: *Charybdis ferriata* and *Portunus pelagicus* (Fig. 5A). China and Thailand get these exports in the form of fresh, frozen, or crab meat (MFD 1973–2022). Patiani Creek appears to have had the most diversity, with eleven different species or groups of species (Fig. 5B). The kinds of crabs that live in brackish water and their geographic range in the Indus Delta have been discussed by Khan *et al*. (2024a).

Three commercial categories of Penaeid shrimp were existed: Jaira, Kalri and Kiddi shrimp (Zalinge *et al*. 1986a; 1987). Twenty distinct Penaeid prawn species were obtained from the study area and are divided into commercial categories as shown in Table 2C and Fig. 5C. The most prevalent of the eight species found within the Jaira group was *Penaeus indicus* (Khan *et al*. 2024b). The findings of this study indicate that although streams are considered to be suitable places for prawns to spawn, they are being overfished to the point where these resources are running out. Zalinge *et al*. (1986a, 1987) and Khan *et al*. (2024a) have identified *Penaeus indicus* and *P. merguiensis* as estuarine species. Prior research has indicated that the intensive fishing of shrimp resources occurs in stream areas and shallow coastal waters through the use of fine-mesh trawl nets, a large number of fishing vessels and the regular use of prohibited fishing gear (Zalinge *et al*. 1986a, 1987; Psomadakis *et al*. 2015; Fanning *et al*. 2016; Khan 2021; Khan and Abbas 2024; Khan *et al*. 2024b). Patiani Creek seems to have more of these prawns than the other streams that were looked into (Fig. 5D). In response, the Sindh government prohibiting catching shrimp during June and July in 1983, although this had little effect on the ongoing problem of a shortage of supplies brought on by widespread overfishing as a result of the expansion of the fleet (Khan 2002).

The other shrimp species excluding the Penaeid shrimps include deep sea shrimp (*Solenocera* sp.), freshwater prawn, carid and Mantis shrimp as given in Table 2D. As shown in Fig. 6A, 95% of the group in this category of shrimp consisted of carid prawns, which were extensively dispersed across the research area. The pure marine species *Solenocera* sp. was found in the Patiani and Wari streams (Fig. 6B). Three different types of aquatic habitats—deep water, shallow water and turbid water—have been identified in the study region by Khan *et al*. (2025). Over the study period, all types of water level rises were seen at every creek; Patiani Creek showed the most changes.

Diverse methods are employed by pelagic and demersal fisheries to catch fish in midwater and at the water's surface. Though they are frequently contrasted, it is frequently unclear how demersal and pelagic species differ from one another. While demersal species are more frequently found in mid-water, most pelagic and demersal species are located close to the bottom. For instance, bentho-pelagic marine species *Trichiurus lepturus* are frequently caught using bottom and pelagic trawl nets. Pelagic fish are widely spread and found in a range of maritime environments. They are found in the upper and midwater levels of the oceans. They include enormous piscivorous fish and apex predators like tunas, billfishes and sharks, as well as tiny forage fish like herrings, mackerels and sardines (Stephenson and Smedbol 2001). Essential food and products for consumer markets, such as fish oil and meal, are sourced from pelagic fisheries. There are three types of gear for catching: static, towing and encircling gear. Pelagic species are more catchable due to their shoaling habit. Within the Scombridae family, three specimens of *Scomberomorus commerson,* two specimens of each *Scomberomorus guttatus* and *Scomberomorus* sp. are the only three genuine large pelagic fish species identified in the study region. The main species in the large pelagic group is *Scomberoides commersonianus*, a member of the Carangidae family, which comprises 61% of the group (Fig. 6C). Of the other species, three are part of the Sphyrnidae family, which makes about 37% of the total. Higher quantities of these large pelagic fish species are found in the Patiani and Mal streams within the study region (Fig. 6D). There were no large pelagic fish in the Khajar and Khar creeks since these fish are maritime species.

Small pelagic fishes appear to be the second biggest category with 48 species or groups of species found in the fish samples collected at the study site. Within the small pelagic fish group, the percentage makeup of the families is shown in Fig. 7A. The leading family is Clupeidae, with 39%, of the total capture. Among the other families are the Hemiramphidae, Scombridae, Elopidae, Dussumieriidae, Belonidae, Engraulidae, Mugilidae, jellyfish, Leiognathidae and Pristigasteridae. Fig. 7B displays the geographical distribution of small pelagic fish species. Issaro Creek has

the most number of species at twenty-nine; Hajamro Creek has twenty-eight, making it the second most abundant. The majority of these small pelagic species inhabit estuaries or shallow coastal waters. Khan *et al*. (2024b) provide a detailed description of the spatial distribution of these small pelagic fish species in the Indus Delta creeks. Even though these species are known to mature swiftly and have short lifespans, statistics of total production and the CPUE of these species are gradually declining (Fanning *et al*. 2016; Khan 2021; Khan and Abbas 2024). There are several obstacles to the management of small pelagic fisheries, including overfishing, growing markets, technological developments and a lack of jobs. The population fluctuations can also impact marine environments ecologically, changing food webs and trophic cascades (Stephenson and Smedbol, 2019). In Pakistan, small pelagic fishes such as sardines, anchovies and scads are caught using seine gear, or locally called "Katra" net (Khan, 1986). Misuse of this encircling gear can also have detrimental effects on habitat when it is utilised in creek regions or very shallow coastal waters and it can also catch juveniles of other commercially important species (Psomadakis *et al*. 2015).

Benthic or bentho-pelagic fish are defined as demersal fish by Froese and Pauly (2023), this implies they reside near to the bottom but are not linked to it. In demersal fisheries, a variety of fishing techniques are employed to catch shellfish and fish on or near the bottom of sea (Khan, 1986; Fanning *et al*. 2016). Fig. 7C and Fig. 7D show the collection of 110 species or species groups that fall into demersal fish category from the study region. It is discovered that ninety species have less than one hundred specimens. Table 2H gives the list of demersal fish species collected from the survey region. While these fish are distributed across the whole research region, their distribution is widely dispersed, with Waddi Khuddi Creek having the most species (53), followed by Patiani Creek (Fig. 8A).

Demersal fisheries are the most lucrative part of fisheries on continental shelves globally, capturing a significant portion of the marine fish supply utilised for human consumption. Everywhere over the past few decades, fishing has risen dramatically, including Pakistan's demersal fisheries. This growth has been attributed to advancements in navigation and fish-finding technology, as well as rise in the number of and power of engine. Pakistan's demersal fisheries are overfished; to preserve a sustainable production, strict control and a reduction in the fishing fleet are required (Fanning *et al.* 2016; Khan 2021; Khan and Abbas 2024). The presence of low-oxygen, upward-sloping water affects the distribution of fish and prawns on the continental shelf. In order to escape low oxygen levels in the ocean, demersal fish and prawns migrate to shallow waters. This eventually improves their availability to fisheries by decreasing their dispersion and increasing their density (Psomadakis *et al*. 2015; Fanning *et al.* 2016).

Freshwater fish comprised 82% of the species *Gudusia chapra*, with *Salmostoma bacaila* coming in second at 14%. The research region's freshwater fish and prawn distribution is shown geographically in Fig. 8B. In addition, five distinct species of freshwater prawns were collected from the region; the most common and widely distributed species in the research area was *Palaemon styliferus*. The Jhang River's high freshwater content and low salinity make it the most popular location for these types of fish and prawns.

Khan (1986) discussed fishing techniques and fishing nets used in coastal waters, such as the most common type, the trawl net. Trawling is a particularly destructive and non-selective method of harvesting fish and prawns in Sindh region. The net is pulled over the ocean floor and grabbed with the help of the boat's motor. The following net types—trawl nets, also known locally as "Gujja," "Gujjo," or "Gujji"; seine nets, also known locally as "Katra"; and set-bag nets, also known locally as "Bulla" or "Bullo"—are completely prohibited from being used in Sindh's creeks, regardless of their size or mesh size (GOS 2010). In shallow coastal waters and Indus delta streams local fishermen used smaller mesh sizes, even though the Sindh government allows prawn trawls with a 25 mm mesh size (GOS, 2016) (Psomadakis *et al*. 2015; WWF 2015; Khan and Abbas 2024). Additionally, it is also forbidden to use these fishing gears in Balochistan coastal waters (GOB 2009). According to Quraishee (1986), more boats and mechanised fishing gear have led to a notable rise in fish harvested in Pakistan, especially along the coast of Sindh. Seasonal fluctuation in river discharge and fishing pressure stretches 30 miles off the coast further hamper catch recovery.

From shallow coastal waters to offshore seas down to a depth of around 100 m, trawlers are in operation. Prior to 2002, these boats only engaged in shrimp trawling, but nearly all trawlers have mechanized trawl winches and use both high opening bottom trawling for fish and shrimp trawling nets, particularly during the months of August and September (Psomadakis *et al*. 2015). This is a result of the technology transferred by foreign flag-fishing vessels under deep-sea fishing permitted by the federal government (Khan and Abbas 2024). Shrimp stocks have been reduced as a result of the operation of such a big trawling fleet and there have also been some ecological effects that might have a significant influence on the biological variety and productivity of the fishing grounds. The usage of nets with tiny mesh sizes, which ultimately capture large numbers of juveniles of both commercially significant and minor food species, is one of the main issues. They are referred to as "trash fish" because of their diminutive size and lack of customer demand. Fishmeal used in animal feed for chicken farms is made from trash fish, which are mostly captured by trawling for higher-value fish, crustaceans and molluscs (Psomadakis *et al.* 2015; Fanning *et al*. 2016). Khan and Abbas (2024) also listed the main problems with the nation's marine fisheries, such as the overcapacity of the fishing

fleet, the use of harmful fishing gear, postharvest losses (on fishing boats, landing spots and during transportation), the destruction of mangroves and marine pollution. The size of the major estuarine finfish, prawns and crabs sampled from the survey region was relatively small, as evidenced by their length-weight relationship. The size range for prawns was 1-6 cm for *Peneaus indicus* and a maximum size range of 4-48 cm for *Leturacanthus savala* (Khan *et al*. 2024b).

Table 3 shows the average catch rate (k/h tow) for each of the many creeks under this study. The season and the creek appear to differ noticeably from one another. Having a maximum value of 0.02 and a minimum of 0.02, the Jhang River catch rates had the lowest standard deviation of 1.68, while the Chann Creek catch rates had the maximum value of 14.24. During the fish stock assessment surveys conducted in 1983–1985, the contiguous distribution among the fish capture was discovered (Abildgaard *et al.* 1986). The value of skewedness ranges in the current study from -0.26 to 2.97. This confirms that the distribution is contiguous (Abildgaard *et al.* 1986) and skewed values larger than +2 at Richhal, Mal, Hajamro, Chann and Waddi Khuddi creeks showed a considerable divergence from the normal distribution as reported by Hair *et al.* (2022). Kurtosis indicates how overly high or flat the distribution is in relation to a normal distribution. Kurtosis values more than +2 were found for Richhal, Mal, Hajamro, Chann, Dabbo and Wadi Khuddi creeks, suggesting that the distribution's peak variation is excessive (Hair *et al.* 2022).

The zone of backwaters, mangrove swamps and other places inside the 10 metre isobath are not included in the data set used to compute biomass. 3,850 square kilometres and 6,476 square kilometres, respectively, are the approximate sizes of these territories (Brandhorst 1986). In a research on nutrients, primary production, zooplankton biomass and fish and prawn larvae, Rizvi *et al*. (1986) discovered that the entirety of the Indus River's intertidal delta supports around 100,000 kg of fish biomass, compared to the approximately 4,000 kg supported by the Gharo-Phitti Creek system. Primary output is sufficient to sustain a respectable fishery in the area despite environmental challenges. In Khober Creek, the Indus Delta, finfish diversity and seasonal abundance were investigated by Amir *et al.* (2016). They discovered that species' relative abundance and biomass ranged from 0.04 to 9.1 kg and 0.01 to 12.14 kg, respectively.

After examining the findings of studies conducted using a variety of trawls and vessels, Brandhorst (1986) agreed with Abildgaard *et al.* (1986) that the optimal biomass total for the shelf region between 10 and 200 m of depth is around 330,000 MT. In the absence of data and it was assumed in 1986 that these creek areas are more productive than the other coastal waters therefore, the double average biomass estimate per square kilometre of the survey area (*i.e*., 15 MT/sq.km), was used by Brandhorst (1986) to calculate the fish biomass in the zone from 0-200 m depth. Table 4 in this study presents the estimated fish biomass for each stream. The average capture rate of each creek was transformed into fish density, which was then multiplied by the survey area of each creek to obtain the biomass of each creek. After extending the projected biomass of each stream under study to the whole area of creeks and mangroves, 9,594 MT were produced, which is 16.61% of the 57,750 MT as stated by Brandhorst (1986). This indicates that the creek zones are also heavily overfished, just like other coastal and offshore seas (Fanning *et al.* 2016; Khan and Abbas, 2024).

Pakistan is a signatory of the UN Sustainable Development Goal and goal 14 related to life below water that aims to conserve and sustainably use oceans, seas and marine resources for sustainable development, focusing on reducing marine pollution, managing ecosystems and combating overfishing. In order to restore fish populations to levels that can give the highest sustainable yield, SDG 14.4 requires that fishing be adequately controlled and that overfishing, illegal, unreported and unregulated fishing, as well as harmful fishing practices, be stopped by 2020. The FRAP assessment report recommended a 50% reduction in the current fishing fleet to replenish the fish stock (Fanning *et al*. 2016). The fishing fleet, on the other hand, is growing annually and has increased by 71.4% between 2011 and 2021 (Khan 2024).

Conclusion

The stream survey is a biological study of marine fisheries resources in creeks throughout numerous survey zones, with a focus on seasonal fluctuations, migratory patterns, fisheries-related issues and suggestions for preserving Pakistan's fish populations. There are 800 species of fish in Pakistan and 241 of them have been identified in the study area. With three distinct meteorological seasons—rainy from June to August, post-rainy from September to December and pre-rainy from January to May—fish harvests are significantly influenced by seasonal variations. The majority of the sample consisted of estuarine species (75%), followed by marine species (23%) and freshwater species (2%). Since fishing was banned in June, capture rates increased. Due to overfishing and rising salt levels, Pakistan's fish yield has decreased since October. The research region had very low harvests of Penaeid shrimp, despite the fact that many fish and shrimp species choose estuaries to be their breeding grounds. Regardless of their size or mesh size, set-bag nets, also known locally as "Bulla" or "Bullo," seine nets, also known locally as "Katra," and trawl nets, also known locally as "Gujja," "Gujjo," or "Gujji," are all strictly forbidden from being used in Sindh's creeks. However, local fishermen do frequently use them there. Creek areas are similarly overfished as other coastal and offshore waterways in the nation, as evidenced by the estimated biomass of the streams under study, which amounts to 9,594 MT or 16.61% of the expected biomass of 57,750 MT in 1986.

To meet the commitment under the UN SDGs, strict enforcement of fisheries laws and their oversight are necessary.

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Author Contributions

Muhammad Wasim Khan: Conceptualized and designed the study, performed the survey, analysed data and wrote the manuscript; Ghulam Abbas: Reviewed the manuscript and supervised this research; Shahnaz Rashid: Helped in data analysis and paper formatting.

Conflict of Interest

The authors have declared no conflict of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable to this paper.

References

Abildgaard NL, MW Khan, M Khaliluddin, S Qureshi, NPV Zalinge (1986). *Stock Assessment of Demersal Fish in Pakistan waters.* Results of bottom trawl survey carried out in 1983-85. Rome. FAO. FAO/UNDP/GOP Marine Fisheries Development Project (PAK/77/033/4)

Ahmed M (1985). Winter and spring abundance of juvenile Penaeid and caridean shrimps in the Indus delta (Pakistan: Northern Arabia Sea). *Pak J Zool* 17:67–70

Amir SA, PJA Siddiqui, R Masroor (2016). Finfish diversity and seasonal abundance in the largest arid mangrove forest of the Indus Delta, Northern Arabian Sea. *Mar Biodivers* 48:1369–1380

ASEAN (1978). *Manual on Pond Culture of Penaeid Shrimp*. FAO/UNDP South China Sea Fisheries Development and Coordinating Programme (SCSP), Manila

Banse K (1984). An overview of the hydrography and associated biological phenomena in the Arabian Sea off Pakistan. *In*: *Marine Geology and Oceanography of Arabian Sea and Coastal Pakistan*, pp:271–303. Haq BU, JD Millman (Eds.) Van Nostrand Reinhold, New York

Bianchi G (1985). *Field guide to the commercial marine and brackish-water species of Pakistan*. Prepared with the support of PAK/77/033 and FAO (FIRF) Regular Programme. FAO species identification sheets for fishery purposes. Rome, FAO

Brandhorst W (1986). Demersal fish resources available for the expansion and development of marine fishery of Pakistan. *In: Proceeding of Seminar on Fisheries Policy and Planning held on 17-21 September 1986*, pp:1–23. Majid A, MY Khan, M Moazzam, J Ahmed (Eds.)

Damhoureyeh SA, SA Ghalib (2014). *An overview of the status and distribution of the mangrove forests and their wildlife in Sindh*, Vol. 8, p:5. SENRA Academic Publishers, British Columbia

Fanning LP, P Medley, MW Khan, T Valinassab (2016). *Comprehensive Assessment of Pakistan's Marine Fisheries Resources to 2015*, p:170. Report prepared for the Fisheries Resources Appraisal in Pakistan Project (UTF/PAK/108/PAK). FI/UTF/PAK/108/PAK, Field Document No 9. Food and Agriculture Organization of the United Nations

Fischer W, G Bianchi (1984). *Western Indian Ocean (Fishing Area 51). Prepared and printed with the support of the Danish International Development Agency (DANIDA)*, pp:1–6 FAO species identification sheets for fishery purposes. Rome, Food and Agriculture Organization of the United Nations

Froese R, D Pauly (2023). *FishBase*. World Wide Web electronic publication. www.fishbase.org

Froese R, D Pauly (2021). *FishBase*. World Wide Web electronic publication. www.fishbase.org

GOS (2016). *Notification about minimum mesh size of the code-end of trawl nets*, p:1. Livestock and Fisheries Department, Government of Sindh

GOS (2010). *Notification about Ban Nets.* Livestock and Fisheries Department, Government of Sindh

GOB (2009). The Balochistan Sea Fisheries (Amendment) Act, 2009

Hair JF, GTM Hult, CM Ringle, M Sarstedt (2022). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM),* 3rd edn. Thousand Oaks, CA: Sage

Hoda SMS (1985). Identification of coastal fish varieties of Pakistan. *Pak Agric* 10:20–26

Hussain AG, MA Burney, SQ Mohiuddin, S Zupanovic (1968). *Analysis of demersal catches taken from the exploratory fishing off the coast of West Pakistan*, p:17. IPFC 13th Session, IPFC (C 68) Symposium

IUCN (2005) *Mangroves of Pakistan Status and Management*, p:121

Jaleel SA, M Khaliluddin (1981). *A check list of Marine Fishes of Pakistan*, pp:1–8. Directorate of Marine Fisheries, Government of Pakistan

Jaleel SA, M Khaliluddin (1972). *A check list of Marine Fishes of Pakistan*. Directorate of Marine Fisheries, Government of Pakistan

Kennedy EBL, KC Buresch, P Boinapally (2020). Octopus arms exhibit exceptional flexibility. *Sci Rep* 10:20872-20881 https://doi.org/10.1038/s41598-020-77873-7

Khan MW (2024). Qualitative Assessment and Seasonal Abundance of Fish and Shrimp Juveniles in the Indus Delta Creek System. *Ph. D. Dissertation*, p:331. Sindh, Pakistan

Khan MW (2021). Status of fish stocks in Pakistan waters (2021). *Prepared for Ministry of Maritime Affairs, Government of Pakistan*, p:24. Food and Agriculture Organization of the United Nations, Islamabad

Khan MW (2002). *Status of Shrimp Fishery in Pakistan*. presented in Seminar on Marine Environment 2002, organized by Centre of Excellence Marine Biology University of Karachi in collaboration with British Council, Department for International Development U.K (DFID) and Scottish Association for Marine Science (SMAS) U.K. from 29-30 January 2002 at Karachi. *Intl J Biol Biotechnol* 4:1–12

Khan MW, G Abbas (2024). Review on Fisheries Resources and the Effect of Marine Pollution in Coastal Waters of Pakistan. *J Zool Syst* 2:23–43

Khan MW, G Abbas (2023). Studies on the Use of Aquatic Food in Pakistan. *J Zool Syst* 1:40–57 https://doi.org/10.56946/jzs.v1i2.246

Khan MW, G Abbas (2020). Evaluation of Temperature, Salinity and Bathymetry in the Indus Delta Creek System. *Sindh Univ Res J Sindh Univ Res J* 52:1-6

Khan MW, G Abbas, S Rashid, H Kaloro, A Rauf (2025). GIS-based classification of habitat, land use and land cover in several creeks within Sindh province's Indus delta. *J Zool Syst* 3:1–12 https://doi.org/10.56946/jzs.v3i1.520

Khan MW, G Abbas, A Fatima, S Rashid (2024a). Studies on the Spatial Distribution and Abundance of Selected Estuarine Fish Species in the Indus Delta Creek System Sindh, Pakistan. *Sarhad J Agric* 40:551–561

Khan MW, G Abbas, S Rashid, A Rahim, A Rauf (2024b). Studies on the Length-Weight Relationship (LWR) of Thirteen (13) *Dominant*

Estuarine Finfish, Shrimp and Crab Species found in Indus Delta Creeks System. Vol. 31 No. 08, (2024) JPTCP (3023 - 3040). DOI: 10.53555/yf3z1387. https://www.jptcp.com/index.php/jptcp/article/view/8615

Khan MY (1986). Fishing techniques in coastal waters of Pakistan. *In*: *Proceeding of the National Seminar on Fisheries Policy and Planning,* pp:345–364. Majid A, MY Khan, M Moazzam, J Ahmed (Eds.). Marine Fisheries Department, Government of Pakistan, UNDP, FAO

Majid A, MW Khan, M Khaliluddin (1992). *Commercially Important Marine Fishes of Pakistan*, p:263. Published by Department of composition, compilation and translation, Federal Government Urdu Science College, Karachi Pakistan

Memon AA (2005). *Devastation of the Indus River Delta*. World Water & Environmental Resources Congress 2005. Anchorage, Alaska: American Society of Civil Engineers. World Wildlife Fund

MFD (1973-2022). *Handbook of Fisheries Statistics of Pakistan*, pp:1–21. Marine Fisheries Department, Government of Pakistan, Karachi

PN-Hydro (2016). *Calculation of Pakistan Coastline length*, p:1. Hydrographic Department, Naval Headquarters, Karachi, Pakistan letter No. HD/0628/II/938 dated 12 April 2016

Psomadakis PN, HB Osmany, M Moazzam (2015). *Field Identification Guide to the Living Marine Resources of Pakistan*. FAO Species Identification Guide for Fishery Purposes. Rome, FAO. 2015. x + 386., 42 colour plates

Quraishee GS (1986). Environmental and Harvesting stresses on fish stock in Pakistan. *In*: *Proceeding of Seminar on Fisheries Policy and Planning held on 17-21 September 1986*, pp:95–103. Majid A, MY Khan, M Moazzam, J Ahmed (Eds.)

Qureshi MR (1955). *Marine Fisheries of Karachi and the coasts of Sind and Makran*, pp:1–80. Central Fisheries Department, Government of Pakistan, Karachi

Raza SQ, MW Khan (2001). Avenues for improving Marine Fish harvesting and Handling. *In*: *Proceeding of National Seminar on Strategic Planning for Fisheries & Aquaculture to face the Challenges of New Millennium*, pp:40–70. Organized by marine Fisheries Department, Government of Pakistan and Food, Agriculture of United Nations (FAO) on May 28, 2001 at Karachi

Rizvi N, LP Fanning (2012). *Creek Surveys Operations Manual – 2012,* p:76. FAO Fisheries Resources Appraisal in Pakistan (UTF/PAK/108/PAK), Food and Agriculture Organization of the United Nations, Karachi, 2012

Rizvi SHN, M Saleem, J Baquer (1986). Productivity of Gharo-Phitti Creek System. Contributed to the National Seminar on Fisheries Policy and Planning. *In*: *Proceeding of Seminar on Fisheries Policy and Planning held on 17-21 September 1986.* Majid A, MY Khan, M Moazzam, J Ahmed (Eds.)

Stephenson RL, RK Smedbol (2019). Small pelagic species fisheries," *In*: *Encyclopedia of Ocean Sciences*, 3rd edn., 503–509. Elsevier Ltd., Amsterdam, Netherlands

Stephenson RL, RK Smedbol (2001). *Small Pelagic Species Fisheries, Encyclopedia of Ocean Sciences*, 2nd edn., pp:468–473. Steele JH (Ed.). Academic Press

Tirmizi NM, Q Bashir (1973). *Shore and Offshore Penaeid of Northern Arabian Sea*, pp:1–71. Publication of Karachi University, Pakistan

Zalinge NPV, M Khaliluddin, W Khan (1987). *Description of the shrimp fishery including a stratified sampling scheme for shrimp landings and effort at Karachi fish harbour, Pakistan.* Karachi Pakistan

Zalinge NPV, M Khaliluddin, MW Khan (1986a). Update of the status of Pakistan's shrimp fisheries and the management implications. *Presented in National Seminar on Fisheries Policy and Planning held on 17-21 September 1986*, pp:77–87

Zalinge NPV, M Khaliluddin, W Khan (1986b). *Results of the sampling programme for juvenile shrimp in the Korangi/Phitti/Gharo creek area of the Indus delta. May 1985-April 1986.* FAO/UNDP Marine Fisheries Development Project, PAK/77/033

WoRMS (2024). *World Register of Marine Species*. Available from https://www.marinespecies.org at VLIZ. Accessed 2024-05-17. doi:10.14284/170

WWF (2015). *Fisheries Resource Appraisal in Pakistan - Creek Survey*, p:122

WWF (2007). *World's top ten rivers at Risk*, Tech Rep

WWF (2005). *GIS Remote Sensing Based Assessment of Mangrove Resources of Selected Project Sites of Indus Delta and Makran Coast*, p:55. World Wildlife Fund for Nature and Natural Resources, Pakistan, Lahore