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Migratory patterns of hilsa shad in the Myanmar Ayeyarwady delta

Lessons for fisheries management

Eugenia Merayo, Kyi Thar Myint, Thida Ei, Myint Khine, Pwint Thu Aye, Thida Lay Thwe, Kimio Leemans, Khin Maung Soe, Michael Akester, Annabelle Bladon and Essam Yassin Mohammed

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Hilsa shad is one of the most important fisheries in Myanmar, providing livelihoods and nutrition to thousands of vulnerable communities. However, overfishing and habitat destruction are putting at risk the sustainability of the fishery. This study aims to expand the knowledge of the ecology of the hilsa fishery, by discussing the seasonality and preferred routes of this migratory fish. This information will help inform policy interventions as to where and when fishery closures are most cost efficient, in order to maximise the reproductivity of the stock and ensure its long-term sustainability.

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Summary

Hilsa shad is one of the most important fisheries in Myanmar, providing livelihoods and nutrition to thousands of vulnerable communities. However, overfishing, climate change, pollution and habitat destruction are putting the sustainability of the fishery at risk.

Other fisheries around the world are now using their knowledge of migratory routes and fish species behaviour to improve conservation plans and create more sustainable fisheries. But in Myanmar, the lack of knowledge on hilsa behaviour is hindering the effectiveness of fisheries management.

This study aims to reduce that knowledge gap, focusing on the characteristics of hilsa migration in the Ayeyarwady Delta in terms of both routes (Ayeyarwady and Pathein routes) and seasonality. A better understanding would improve and inform fisheries policy interventions in Myanmar as to where and when fishery closures are most cost efficient, to maximise the reproductivity of the stock and ensure its long-term sustainability.

Section 1 provides an overview of the hilsa shad fishery in Myanmar, where hilsa are mainly distributed along the Ayeyarwady Delta, migrating from coastal areas though brackish waters to freshwater areas. Section 2 describes the study sites chosen and their relevance as habitats for hilsa in the three ecological zones. It also outlines the methods used for sampling the fish and collecting and analysing their data. Section 3 presents and discusses the results, while Section 4 provides policy options and recommendations. Finally, Section 5 discusses the main summary and conclusions.

The following policy interventions are recommended in each of the three ecological zones in the Ayeyarwady Delta:

- In the marine environment, we recommend a ban on catches of adult hilsa fish in July and August, when the largest brood mature fish are found in both the Ayeyarwady and Pathein route areas.
- In brackish waters, we recommend the protection of juveniles in the Maubin–Ayeyarwady route brackish area. During October, introduce a total ban on fishing in this nursery ground. In addition, we also suggest a similar measure to protect juveniles during March and April due to the abundance of juveniles in the area, likely linked to a secondary spawning season in freshwater in February.
- In freshwater areas, as suggested by Bladon et al. (2019), we recommend the special protection of spawning and nursery areas in September and October, when the main spawning season takes place.
- In all areas and at all times of the year, we suggest the introduction of a minimum landing size for hilsa so the catch of smaller immature fish is banned. This should increase the reproductive potential of the stock. This minimum size should be set at around 34cm in total length. According to our estimation on length at maturity, hilsa under this length can be considered immature.
- The introduction of the ban regulations suggested above implies reductions in income and food from fishing for fisher communities. In order to support their livelihoods during periods of fishery closure and increased compliance, compensation for lost income should be provided. The design of an incentive management scheme for Myanmar that compensates fishers in times of fishery closures, delivering both environmental and social sustainability, is the main objective of the Darwin Initiative-funded project this study is part of.
- In order to prevent a disproportionate burden on fishers, alternative policy options should be explored that do not include a total ban on fishing. For example, in marine areas in summer, when large hilsa fish are abundant and represent an important income source for fishers, the introduction of a fishing ban is likely to encounter strong opposition. Instead, introducing a limit on total catches or restrictions on the fishing access to the marine area during those months may be more appropriate. This scheme could be combined with the designation of a no-take marine area that protects marine brood mature fish to ensure reproduction is successful. The country capacity in terms of monitoring and enforcement of this type of regulation needs to be analysed, as well as the feasibility and potential benefits of a co-management scheme.
- Climate change is likely to impact how hilsa reproduces and migrates, so any management mechanism should be designed in a way that accounts for this uncertainty and is flexible enough to adapt to potential climate-induced changes in the stock.

Abbreviations and acronyms

BW	Body weight
DoF	Department of Fisheries, Myanmar
GSI	Gonadosomatic index
GW	Gonad weight
IIED	International Institute for Environment and Development
TL	Total length

Glossary

Anadromous: fish that migrate from marine areas to freshwater to spawn

Brackish waters: waters with higher salinity than freshwater, but lower salinity than saline waters, generally found in estuaries

Brood fish: sexually mature fish that are ready to spawn

Gonadosomatic index: a measure of reproductive capacity of fish, which estimates gonad weight as a proportion of total body weight

Juveniles: young fish that have not reached sexual maturity

Nursery areas: areas where young fish grow

Otolith analysis: a technique used in fisheries management and fisheries biology that allows tracking fish movement within different habitats and areas. The concentration of trace elements and isotopes in fish vary according to the environments they have been in

Pelago-neritic fish: fish that inhabit marine near-shore waters

Recruitment: the number of young fish entering a population in a given period

Spawning: the deposit of large quantities of eggs in water

Spent fish: fish that have just spawned and released their eggs

Telemetry: methods used to obtain information on wild fish, such as echo-sounders, or video and electronic tags

1

Introduction

Hilsa shad (*Tenualosa ilisha*) is a migratory fish species and one of the most important commercial fisheries of the Indo-Pacific region. While hilsa is distributed along the coasts of the Indian Ocean, from the Arabian Peninsula to Thailand and Northern Indonesia, up to 90% of catches come from Bangladesh, Myanmar and India (Milton 2010).

In Myanmar, fisheries are the fourth largest contributor to national GDP, providing jobs for more than 3 million people and a source of income for around 12–15 million (Baran et al. 2018). While hilsa only represents 1–4.5% of national fish production (DoF 2018), it is relevant in terms of exports, amounting to almost US$34 million in 2012–13 and is one of the most valuable fish species per unit weight for the external market (DoF 2018). It is also a major source of income for many vulnerable fishing communities (Khaing et al. 2018) and is important for food security in the region (Lauria et al. 2018).

However, overfishing, habitat destruction and loss of habitat connectivity are threatening the sustainability of the hilsa fishery in Myanmar (BOBLME 2015; Conallin et al. 2019). Hilsa shad stocks are overfished (Milton 2010), despite regulations in place that establish temporal closures to protect fish spawning and recruitment (for example, the Freshwater Fisheries Law 1991). Hilsa is often targeted during spawning runs and juveniles are caught using small-mesh fishing nets, reducing recruitment (Baran et al. 2015; Khaing et al. 2018). Regulations are not generally enforced, and their design does not consider the spawning and migratory seasonal patterns of hilsa (Tezzo et al. 2018).

Climate change and pollution are also leading to increases in turbidity. Variability of flooding is changing hilsa migration and spawning patterns. Hilsa fecundity is declining, likely linked to habitat degradation (Miah 2015). Increasing water pollution is preventing upstream and downstream migration and blocking access to spawning sites, endangering migratory fish populations (Nasir 2016). Fish migratory species like hilsa are especially vulnerable to river fragmentation and the decrease in connectivity between riverine and coastal zones (Hossain et al. 2016). The construction of dams, barrages and fences for flood control and irrigation without proper fish passages have affected hilsa spawning and migration, because they impede the movement of fish and affect the depth and discharge of rivers (Mizanur 1997; Roomian and Jamili 2011), threatening the sustainability and successful reproduction of these stocks (Rahman 2001).

Hilsa belongs to the Clupeidae family and is a pelago-neritic fish. It can reach up to 65cm in length and most fish are 30–35cm long at two years of age (Haldar and Amin 2005). Hilsa are anadromous in nature and live most of their lives in the sea, migrating upstream to freshwater areas for spawning (Pillay and Rao 1963). In this migratory journey, hilsa usually cover long distances – up to 1,200km (Pillay et al. 1963) and up to 700km in Myanmar (Kyaw 1953). It swims up to 70km a day, which makes it a fast-swimming fish (Pillay et al. 1963).

Previous studies indicate that hilsa breeding takes place in freshwater areas, where larvae hatch from the free-floating eggs. Young hilsa remain in their nursery grounds in rivers and estuaries for 6–10 weeks, where they feed and grow. Then, and after developing their ability to adapt to salinity, they descend to marine areas for further breeding and growth. In general, when hilsa reach 10–16cm long at around 5–6 months, they have already made their way back to the sea. They will return to the rivers as mature breeding adults at 1–2 years old, completing their lifecycle (Reuben et al. 1992; Haroon 1998). According to a recent genetic study of hilsa in Bangladesh by Asaduzzaman et al. (2019), mature hilsa migrate for spawning to the same rivers where they were born and nursed. Hilsa breed all year round in Myanmar, with spawning activity peaks occurring in August–September. There is also evidence of additional spawning seasons in January–February and April–May (Bladon et al. 2019). Young fish spawning for the first time generally spawn in the lower reaches of the river, due to their sensitivity to salinity changes. Older fish spawning for the second or third time will generally spawn in the upper levels of the river (Rahman and Cowx 2006).

Anadromous fish like hilsa generally exhibit a variety of migratory behaviours to adapt to the diversity of physical and hydrodynamic factors they encounter as they move between fresh and saline waters (see eg Kemp et al. 2012; Goodwin et al. 2014). Migration patterns differ between different hilsa population groups or subgroups. In the northern part of the Bay of Bengal, two hilsa stocks show a particular behaviour: one completes its life cycle in freshwater areas and never migrates to the sea, while the other lives in the marine environment and spawns in brackish waters, never migrating to freshwater areas (Hossain et al. 2019). Substantial variations in migratory patterns by location and even at individual level have been assessed for other fish species (Eiler et al. 2015), which adds to the complexity of managing migratory stocks.

Two main migration periods for hilsa are generally described in the literature in the Bay of Bengal: one from July to October, during the southwest monsoon season, and another in winter, from January to March. During the monsoon migration, around 90–95% of catches consist of mature fish, while during the period of winter migration the catch is mixed and both mature and immature fish are found (Ahsan et al. 2014). The peak breeding period is widely thought to be in October, during the full moon (Haldar 2004), and hilsa reproduction is believed to be heavily influenced by the lunar cycle (Rahman and Cowx 2006). A variety of physical, chemical and biological factors affect fish migration (Lagler et al. 1962). These include, for example, water depth, temperature, current velocity, salinity, food availability or the state of sexual maturity of the fish (Bhaumik and Sharma 2011). During the southwest monsoon season, the increased flow of the rivers and their average temperature seem to be favourable for hilsa migration. Changes in rainfall that influence depth and hydro-ecological conditions have an impact on the migration level and consequent fish abundance in subsequent periods (Ahsan et al. 2014). Climate change resulting in changes in river flow dynamics is having a negative impact on hilsa spawning grounds (Miah 2015).

In Myanmar, hilsa are mainly distributed along the Ayeyarwady Delta, migrating from coastal areas though brackish waters to freshwater areas. Baran et al. (2015) suggest this migration takes place through three main routes: the Pathein River, the Ayeyarwady River in the central dry zone and the Ayeyarwady River in the delta. Despite the lack of data on migratory behaviour of hilsa in Myanmar, Baran et al. (2015) used local fisher knowledge to identify two periods of upstream migration: one in the wet or southwest monsoon season (August to October or even December), and one in the dry season around March. Fishers were mostly unclear about patterns of downstream migration, tentatively identifying two periods: one in the dry season, from April to May, and another one during the monsoon season, from July to September. This survey identified the Ayeyarwady section around Hinthada (Figure 1) and extending from Zalun to Monyo, as the most important hilsa spawning site, suggesting it should be a priority for fisheries management and conservation.

Similarly, two different migratory patterns have been identified for hilsa in Bangladesh and India (Ahsan et al. 2014). The first and most important is associated with the southwest monsoon season. During the monsoon, when all rivers are flooding, hilsa swim against the flow to return to the river as breeding adults. This migration takes place mainly in July and August, although it continues until October. There is another migratory period in winter, during February and March. During the migratory periods, the hilsa catch in rivers increases and 80% of females are found in high maturity stages and ready to spawn. Juveniles are found from February to May in foreshore and riverine areas of Bangladesh (Ahsan et al. 2014). In Myanmar, immature hilsa were most abundant in the freshwater zone, where most spawning activity occurs in August and September (93% and 94% respectively), declining to a low of 27% in April (Bladon et al. 2019).

In Bangladesh, seasonality and location of spawning and migration of hilsa have been widely studied (see for example Hossain et al. 2018 for a review). This has informed fisheries management plans and regulations, such as the establishment of hilsa nursery sanctuaries where hilsa fishing is banned in spawning-ground sanctuaries in March and April. There is also a ban on catching juveniles from November to May, and a ban during the 11-day peak spawning period in October during the full moon (Rahman et al. 2011, Alam 2012:

224–238). This is also the case for other fisheries around the world, where knowledge of migratory routes and behaviour of fish species is leading to improved conservation plans and more sustainable fisheries.[1]

In Myanmar, the lack of knowledge on hilsa behaviour is hindering the formulation of an effective fisheries management scheme that protects the resource and those who depend on it for a living. This study aims to reduce that knowledge gap. A better understanding of the characteristics of hilsa migration in the Ayeyarwady Delta – in terms of both routes and seasonality – can enhance the effectiveness of fisheries policy interventions. Benefits are twofold: science-based management is more effective and so less costly for governments, in terms of value for money. In addition, it minimises the cost for local fishing communities, as fishing restrictions are accurately targeted in terms of time and location. Following the Bangladesh example, this will help decision makers when deciding on which areas should be preferentially protected, through spatial and temporal closures, to facilitate hilsa migration and improve its reproductive potential and therefore improve the sustainability of the fishery.

According to the literature, identification of actual migratory routes requires the use of tagging and telemetry techniques (Landsman et al. 2011; Eiler et al. 2015) or biochemical analysis (Cooke et al. 2008; Elsdon and Gillanders 2003; Hermann et al. 2016). However, due to resource constraints and the limitations introduced by the type of data available, we have taken an indirect approach as explained in the methodology section. We aim to infer hilsa migratory patterns by studying the characteristics of the hilsa population and environmental conditions throughout the year in the three different ecological habitats: coastal waters and brackish and freshwater areas.

This report complements the study 'Spawning seasonality of hilsa (Tenualosa ilisha) in Myanmar's Ayeyarwady Delta' (Bladon et al. 2019) and was conducted as part of the Darwin Initiative-funded project Carrots and sticks: incentives to conserve hilsa fish in Myanmar (Darwin-Hilsa^{MM}).[2] The project is led by the International Institute for Environment and Development (IIED) in partnership with WorldFish Myanmar, Network Activities Group (NAG), the Department of Fisheries (DoF) and the Zoology Department of Yangon University. The project aims to design and implement an incentive-based scheme for the sustainable management of hilsa in the Ayeyarwady Delta that also supports the local fishing communities who currently depend on the resource. First, we describe the methods used for sampling the fish and collecting and analysing their data, then we present and discuss the results, before providing policy options and conclusions.

[1] For example, see the Migratory Fish Management and Restoration Plan for the Susquehanna River Basin in USA (SRAFRC 2010) or the current Managing and restoring aquatic EcologicAl corridors for migratory fiSh species in the danUbe RivEr baSin (MEASURES) project in the Danube River basin – although there are plenty of challenges (McIntyre et al. 2015). See www.interreg-danube.eu/approved-projects/measures
[2] See www.iied.org/carrots-sticks-incentives-conserve-hilsa-fish-myanmar

2

Methods

2.1 Study sites

In the Ayeyarwady[3] Delta region, nine study sites were selected following consultation with township-level fisheries managers from the Department of Fisheries (DoF) of the Ministry of Livestock, Fisheries and Rural Development of Myanmar. We based our selection on the sites' relevance as habitats for hilsa and accessibility in the three ecological zones: saline, brackish and freshwater (Figure 1).

According to Baran et al. (2015), migration of hilsa takes place through two main paths: the Pathein River route and the Ayeyarwady River route in the delta (referred to as the Pathein route and Ayeyarwady route in the rest of this report). Hilsa are reported to migrate as far north as the confluence of the Ayeyarwady and Chindwin Rivers in Sagaing Region. However, our study did not look at migrations this far north. Six of the nine townships we sampled belong to the Ayeyarwady route: Labutta, Mawlamyinegyun and Pyapon in coastal areas; Maubin in brackish waters (and seen as especially important for hilsa migration due to the convergence of the Maubin, Yangon and Toe rivers); and Danuphyu in freshwater areas. Hinthada township, in a freshwater area, is an important spawning ground for hilsa. It is where the Ayeyarwady and Pathein routes converge and so belongs to both. In this latter route, the townships of Hainggyi (coastal area) and Ngapudaw and Pathein (brackish waters) were also sampled.

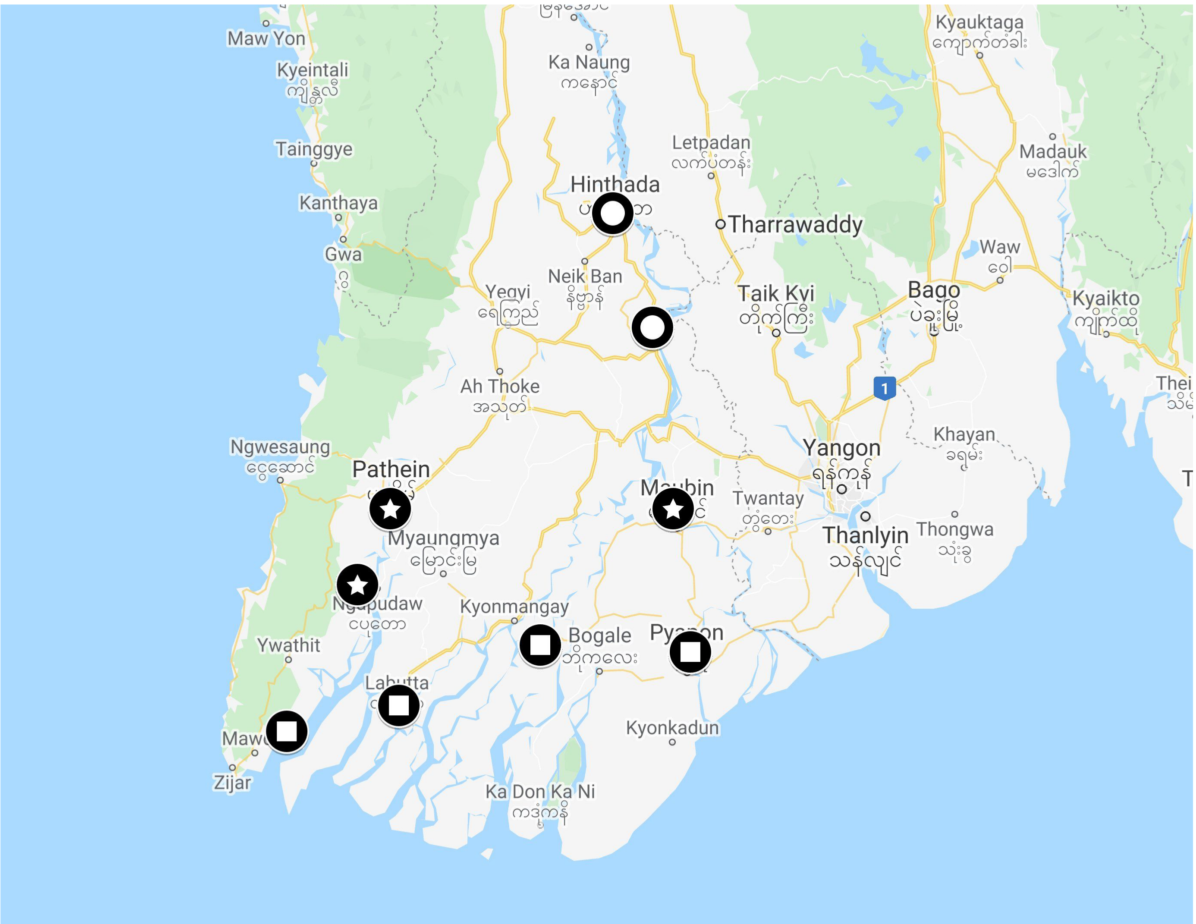
2.2 Data collection

Table 1 shows the number of specimens collected by township within each ecological area and within each migratory route. The sub-sample includes only female hilsa, for which gonad weight and length were measured. A total of 8,793 hilsa fish were sampled in fish landing sites, from November 2017 to November 2018 during the last week of each month. A team of scientists from Yangon University recorded the weight and length of each fish. A randomly selected sample of these fish, 942 in total, were also dissected to assess their gonad weight and length – 525 of these were female hilsa (Table 1).

Some specimens were measured and dissected at the collection place while others – 519 of them – were transported by car to the Yangon University Zoology Department laboratory, within 24–36 hours of collection. During transportation and before measuring at the laboratory, the fish were stored in ice. Total length (TL) of each fish was measured using a vinyl measuring sheet in centimetres. Body weight was measured using a digital balance (Electronic Compact Scale SF-400A) accurate to 1 gram.

[3] Ayeyarwady can refer to a number of things: a region, a delta, a river and a migratory route. The Ayeyarwady region comprises most of the Ayeyarwady Delta, in which the main river is the Ayeyarwady River. This river is also the main avenue of migration through the Ayeyarwady migratory route. The Pathein route via the Pathein River does not include the Ayeyarwady River. However, it is located in the Ayeyarwady Delta and region.

Figure 1. Map of surveyed townships in the Ayeyarwady Delta Region



Notes: (from left to right) Hainggyi (P), Labutta (A), Mawlamyinegyun (A) and Pyapon (A) townships in saline areas (squares); Ngapudaw (P), Pathein (P) and Maubin (A) townships in brackish waters (stars); and Hinthada (A,P) and Danuphyu (A) in freshwater areas (circles) (P = Pathein route, A = Ayeyarwady route). Source: adapted from Google Maps

Table 1. Number of hilsa collected by township within each ecological area and migratory route

MIGRATORY ROUTE	ECOLOGICAL AREA	STUDY SITES	RIVERS	SAMPLE SIZE	SUB-SAMPLE
Ayeyarwady	Saline	Labutta	Ywae/Pyan ma Lut	908	68
		Mawlamyinegyun	Hlaing	1,083	56
		Pyapon	Pyapon	962	39
	Brackish	Maubin	Toe River	913	55
	Freshwater	Danuphyu	Ayeyarwady	1,010	94
		Hinthada*	Ayeyarwady	868	70
Pathein	Saline	Hainggyi	Nga Won/Thet kae Thoung	1,004	31
	Brackish	Ngapudaw	Nghat Pauk/Thet kae Thoung	970	55
		Pathein	Nga Won/Thet kae Thoung	1,075	57
	Freshwater	Hinthada*	Ayeyarwady	868	70

*As mentioned, in Hinthada township both routes converge so for example, adult hilsa sampled here could have reached this freshwater area through either route.

2.3 Data analysis

Assessing the migratory behaviour of fish is generally performed using tagging methods and telemetry (Landsman et al. 2011; Núñez-Rodríguez et al. 2015) or biochemical studies such as otolith analyses (Milton and Chenery 2003; Hermann et al. 2016). However, due to budget constraints and data availability, we used a different approach. Length-based methods – length–frequency and length–weight analysis – are generally used in data-limited fisheries to assess the fish population status (Pauly and Morgan 1987). We have taken a similar approach with the aim of identifying indirectly the likely migratory route and seasonality of hilsa in Myanmar. This method provides a way of inferring migratory seasonality of fish in data-limited contexts and when the use of direct methods such as telemetry or otolith analysis is unfeasible due to the lack of human and financial resources in country. Length–frequency estimations give us information on the abundance of juveniles and mature fish in each ecological zone, on a monthly basis. We used maturity analysis and the gonadosomatic index (GSI) to assess the level of sexual maturity of the fish in each area. By analysing length–weight in combination with sexual maturity data, we aimed to infer hilsa seasonal migratory patterns and suggest priority areas for fisheries management and conservation in order to improve the sustainability of the resource in Myanmar.

2.3.1 Gonadosomatic index

To supplement the information provided by the length–frequency analysis, we have estimated the monthly gonadosomatic index (GSI) of female hilsa by township, despite the small sample at township level. GSI is calculated by dividing the gonad weight (GW) by the body weight (BW) (GSI=100*(GW/BW) and gives an indication of the state of sexual maturity of the fish, as the size of the gonads increases with increases in the reproductive maturity of the fish, reaching a maximum just before spawning and a minimum just after. High GSI indicates sexually mature fish that are about to spawn in the area or are moving to other areas for spawning. Low GSI is associated with fish that have still not reached sexual maturity or spent fish that are on their way downstream after spawning. Therefore, GSI dropping from high to low values indicates either spawning (if in spawning areas) or the upstream movement of brood fish towards spawning areas. We have only analysed GSI for female hilsa due to the bigger size of their gonads, which increases the reliability of the gonad measurement in comparison to male gonads.

The small sample size of female hilsa for which we have measured the gonad weight (and therefore, have information on GSI) per month at township level, implies that GSI results should be considered carefully. In recognition of this, we have also used other length–frequency related indicators to reach our conclusions.

2.3.2 Maturity analysis

We divided the sampled hilsa into two groups based on their total length, which was taken to indicate maturity. We followed the method suggested by Bladon et al. (2019) and estimated length at maturity using the sample of sexed fish. Our results suggest that males equal to or longer than 34cm were mature and females equal to or longer than 34.5cm were mature. We then applied the female estimate to the whole sampled population. The abundance of mature fish in brackish and freshwater areas in certain periods of the year gives an indication of migratory seasonality, as these fish are likely moving through these areas for the purpose of spawning. The presence of immature fish is linked to spawning and nursing periods and so indicate when and where hilsa spawn, nurse and migrate downstream towards marine areas as young fish for further maturation.

2.3.3 Length–frequency analysis

We used length–frequency analysis to identify those areas and months in which small fish – juveniles – and mature fish were abundant. Class intervals of 10cm were established, from the smallest to the largest fish. We assessed minimum and maximum length and distribution of fish by size classes, for every month and for each township belonging to any of the two hilsa migratory routes (Ayeyarwady and Pathein), and the three ecological zones – saline, brackish and freshwater.

The abundance of juveniles helps identify spawning and nursery grounds, while the presence of mature fish in brackish and freshwater areas indicates either upstream migration for breeding or downstream migration as spent fish. If abundance of large fish coincides with high sexual maturity levels, they are likely migrating upstream for spawning. If the maturity levels are low, they are likely moving downstream towards marine areas. Abundance of the smallest fish indicates spawning or nursing ground, while the presence of medium-sized immature fish likely indicates downstream migration.

3

Results and discussion

For this study, we assumed that there are two main migratory routes of hilsa in Myanmar, as suggested by Baran et al. (2015): the Ayeyarwady and the Pathein routes. In the Ayeyarwady route, the townships of Labutta, Mawlamyinegyun and Pyapon were sampled in saline waters; and Maubin in brackish waters. In the Pathein route, the sampling included the township of Hainggyi in saline areas and Ngapudaw and Pathein in brackish waters. Also, in freshwaters, we assessed the townships of Danuphyu (Ayeyarwady route) and Hinthada (which belongs to both routes). The results are presented at township level by migratory route, and within each migratory route by ecological area.

3.1 Ayeyarwady route

3.1.1 Saline areas

In Labutta, sampled hilsa ranged from 21 to 54cm in total length. From October to December and during summer (May–August), mature fish were more abundant (83–100% of the sampled population; see Table 2) and the largest individual hilsa were found (Figure 2). The smaller fish in this township – less than 30cm long – were predominantly found from January to April (20–40% of the sampled population; see Figure 2), and immature fish were also abundant in September

Table 2. Monthly data on minimum and maximum total length and maturity of hilsa, Labutta

LABUTTA	N	MIN TL	MAX TL	% MATURE HILSA	% IMMATURE HILSA
Nov 2017	55	23.9	49.5	38	62
Dec 2017	54	22.3	48	93	7
Jan 2018	65	21.4	48.5	9	91
Feb 2018	100	21.1	48.5	66	34
Mar 2018	100	21	48.5	33	67
Apr 2018	53	21.5	46.8	57	43
May 2018	84	32	54	83	17
Jun 2018	50	35.5	44.2	100	0
Jul 2018	50	38.2	49.9	100	0
Aug 2018	50	40.5	45.5	100	0
Sep 2018	50	30	34	0	100
Oct 2018	101	37.5	52.3	100	0
Nov 2018	96	35.7	52.5	100	0

(100% of the sampled population; see Table 2). In this township, female GSI values peaked in April–May, dropping and remaining low from June to September (Table 5 and Figure 3).

In Mawlamyinegyun, the total length of hilsa varied between 4.4 and 59.5cm. Mature fish were especially abundant from March to November, representing 76–100% of the sampled population (Table 3), and the largest fish were found in September, when more than 20% of the sample were longer than 50cm (Figure 2). Immature fish were abundant in January (68% of the population; see Table 3). In December and January, there was a concentration of hilsa smaller than 20cm, representing 53% and 67% of the population respectively (Figure 2). Female GSI values were highest in July, dropping from August to October (Table 5 and Figure 3).

Table 3. Monthly data on minimum and maximum total length and maturity of hilsa, Mawlamyinegyun

MAWLAMYINEGYUN	N	MIN TL	MAX TL	% MATURE HILSA	% IMMATURE HILSA
Nov 2017	55	35	49	100	0
Dec 2017	100	3.5	50.9	47	53
Jan 2018	137	4.4	48.5	32	68
Feb 2018	137	8.9	50.5	53	47
Mar 2018	100	25	51	85	15
Apr 2018	107	28	52.1	97	3
May 2018	50	31.3	49.7	90	10
Jun 2018	50	39	51.8	100	0
Jul 2018	49	32	42.2	92	8
Aug 2018	50	35	44	100	0
Sep 2018	48	31.5	59.5	94	6
Oct 2018	100	22.3	52.1	76	24
Nov 2018	100	22	50.2	83	17

Table 4. Monthly data on minimum and maximum total length and maturity of hilsa, Pyapon

PYAPON	N	MIN TL	MAX TL	% MATURE HILSA	% IMMATURE HILSA
Nov 2017	55	30.5	61	67	33
Dec 2017	52	35	56	100	0
Jan 2018	63	25.7	50.5	79	21
Feb 2018	103	24	51	80	20
Mar 2018	101	24	51.2	81	19
Apr 2018	84	29	51	93	7
May 2018	57	31	51	96	4
Jun 2018	50	40	47.2	100	0
Jul 2018	50	37	54.5	100	0
Aug 2018	50	34.5	45	100	0
Sep 2018	97	35	52.3	100	0
Oct 2018	100	30.3	52.1	97	3
Nov 2018	100	24	52	91	9

In Pyapon, sampled hilsa varied from 24 to 61cm in total length. Mature fish were dominant throughout the year (67–100% of the population, Table 4), while the largest fish were found from April to July and in October and November 2018, when 77–100% of the sample were 40cm or longer (Figure 2). Immature fish represented 20% of the population from January to March (Table 4), and the smaller fish were found during this period in this township (Figure 2). Female GSI values peaked in August and dropped in September and October (Table 5 and Figure 3).

In the Ayeyarwady route, mature hilsa in saline areas are most abundant in summer (June–August) and in October–November. Large mature fish are prevalent during the summer months in the three townships, mainly in July and August. GSI values suggest that it is mainly in July and August when large mature hilsa start upstream migration, especially in the townships located in the east of the sampled area (Mawlamyinegyun and Pyapon). In October, large mature hilsa were abundant here , while the GSI levels recorded were lowest. These large fish were likely spent and had entered marine areas after downstream migration from spawning grounds. In January, immature hilsa were abundant in the marine area (most likely juveniles reaching marine areas after having been born and nursed in freshwater areas).

Figure 2. Percentage of hilsa by size class, month and township in saline areas in Labutta, Mawlamyinegyun and Pyapon

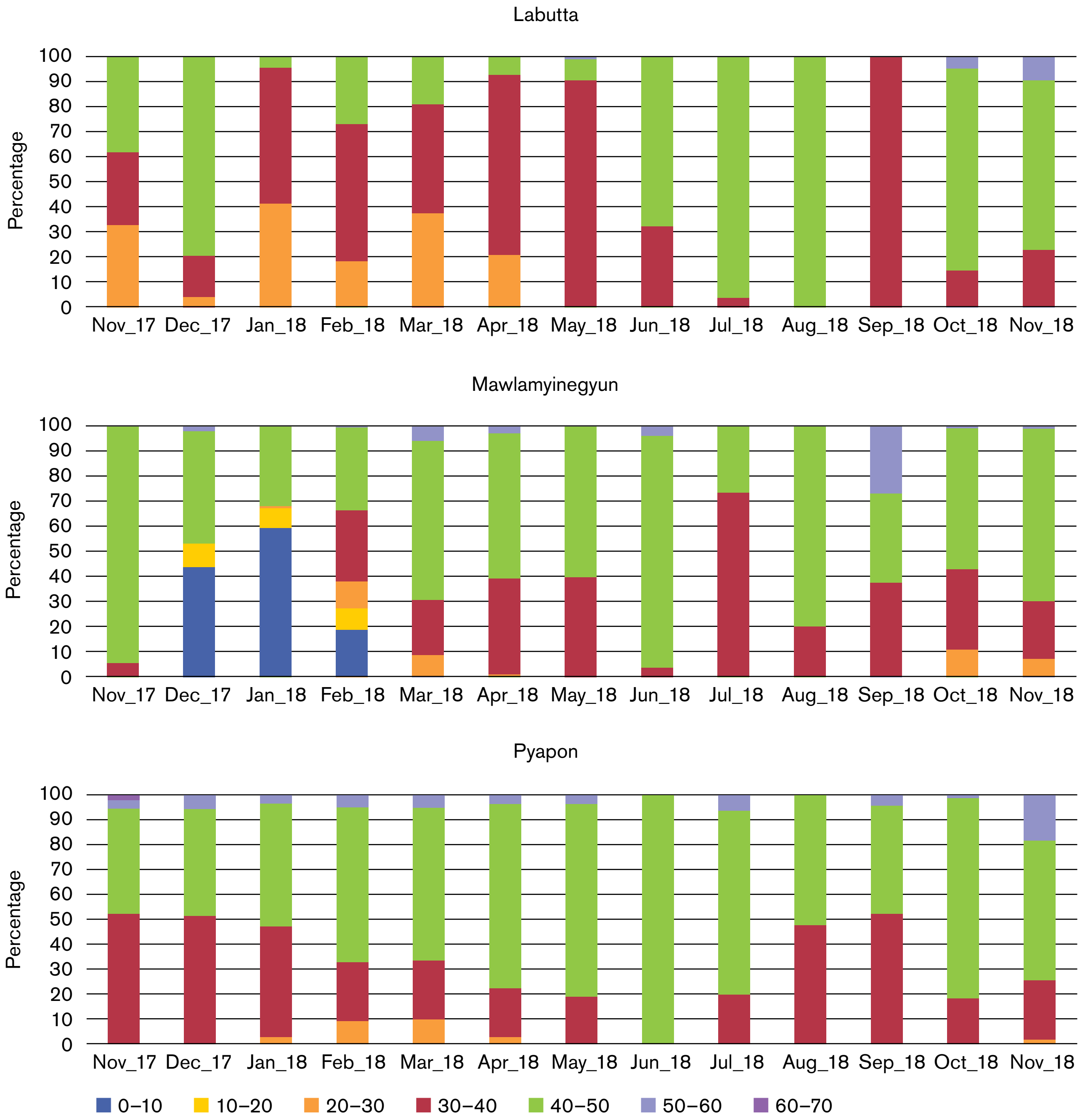
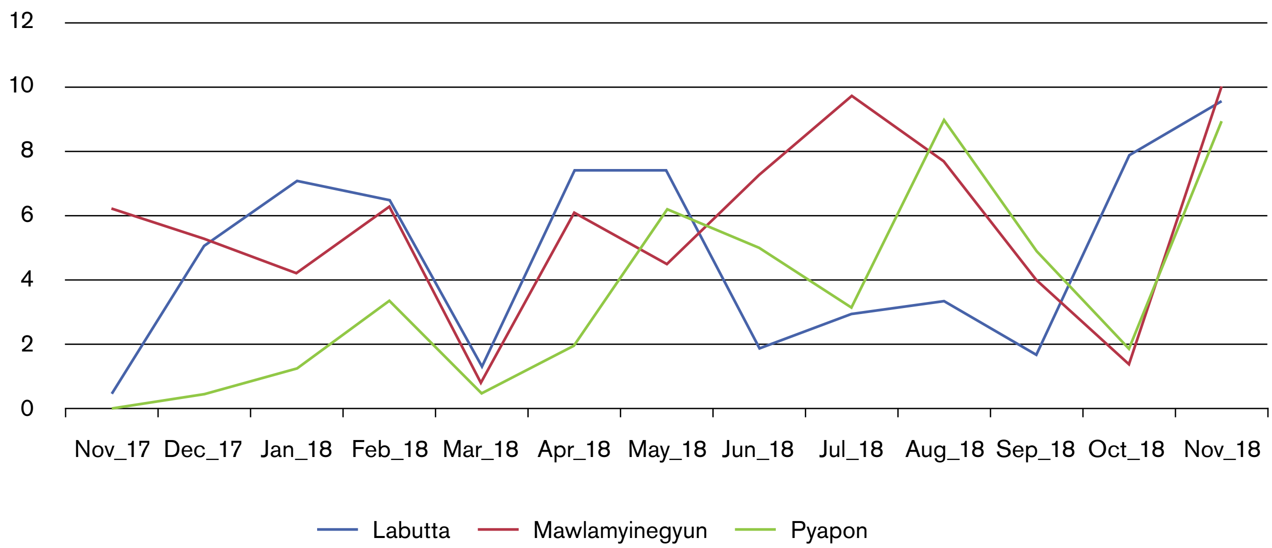


Table 5. Monthly GSI of female hilsa in Labutta, Mawlamyinegyun and Pyapon

	LABUTTA		MAWLAMYINEGYUN		PYAPON	
	N	GSI, FEMALES	N	GSI, FEMALES	N	GSI, FEMALES
Nov 2017	2	0.5	4	6.2	0	–
Dec 2017	2	5.1	3	5.3	1	0.5
Jan 2018	7	7.1	5	4.2	3	1.3
Feb 2018	11	6.5	7	6.3	1	3.4
Mar 2018	2	1.3	1	0.8	1	0.5
Apr 2018	4	7.4	1	6.1	3	2
May 2018	2	7.4	3	4.5	2	6.2
Jun 2018	5	1.9	8	7.3	4	5
Jul 2018	8	3	4	9.7	6	3.2
Aug 2018	7	3.4	6	7.7	4	9
Sep 2018	8	1.7	3	4	4	4.9
Oct 2018	6	7.9	8	1.4	7	1.9
Nov 2018	4	9.5	3	10	3	8.9

Figure 3. Monthly GSI of female hilsa in Labutta, Mawlamyinegyun and Pyapon



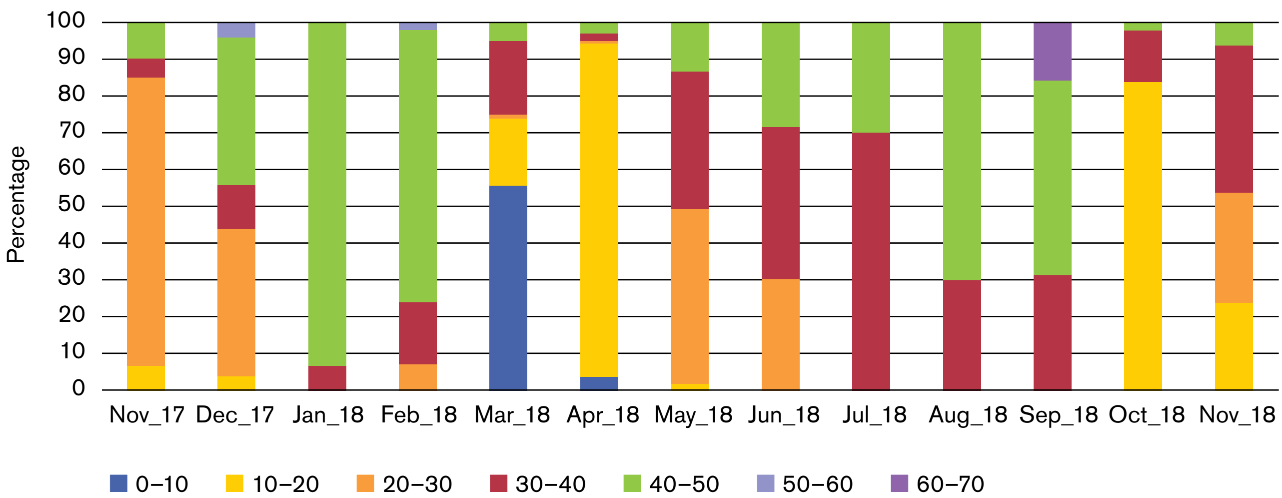
3.1.2 Brackish areas

In Maubin, sampled hilsa ranged from 8.5cm to 65.2cm in total length. Mature fish were abundant in January–February and from June to September (66–97%; see Table 6). The largest fish were found in January–February and August–September, when 69–93% of the sampled population measured 40cm or more in length (Figure 4). On the other hand, immature fish dominated from March to April and in October–November (76–95%; see Table 6 and Figure 5). Smaller hilsa of less than 20cm in length were found in March–April and in October (74–94% of the sampled population; see also Figure 6). Female GSI values peaked in August, dropping during September and October (Table 7 and Figure 5).

Table 6. Monthly data on minimum and maximum total length and maturity of hilsa, Maubin

MAUBIN	N	MIN TL	MAX TL	% MATURE HILSA	% IMMATURE HILSA
Nov 2017	60	19	49	12	88
Dec 2017	50	19	51	52	48
Jan 2018	73	31.5	48.2	97	3
Feb 2018	112	22.5	50	90	10
Mar 2018	100	8.5	45	24	76
Apr 2018	106	9.4	44.3	5	95
May 2018	61	16.5	43	44	56
Jun 2018	50	24.2	42.7	66	34
Jul 2018	50	33	48.5	92	8
Aug 2018	50	33.7	45.5	96	4
Sep 2018	51	31.2	65.2	88	12
Oct 2018	50	10.5	41.2	10	90
Nov 2018	100	16.5	49	24	76

Figure 4. Percentage of hilsa by size class, month and township in brackish areas in Maubin

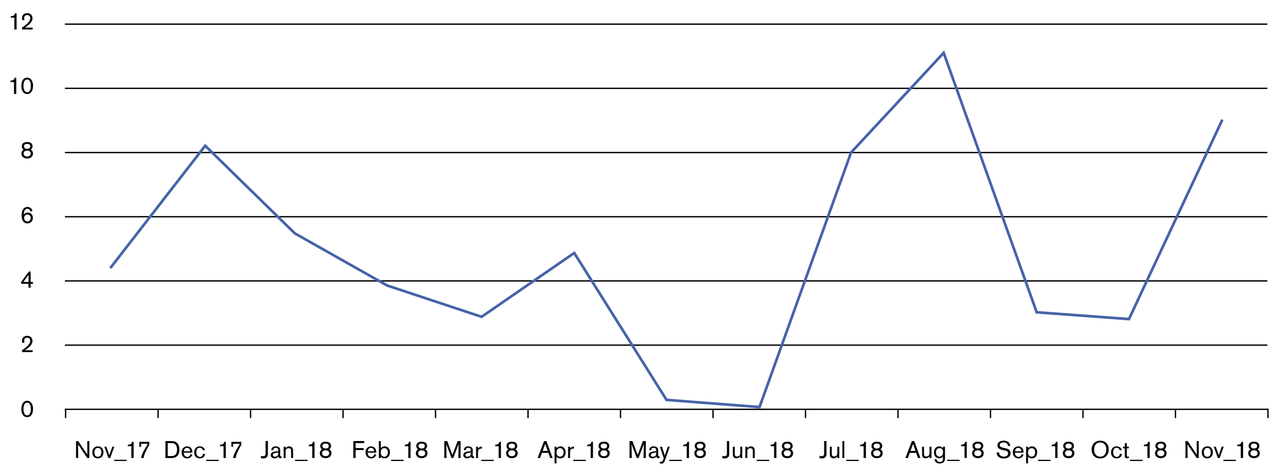


In brackish waters of the Ayeyarwady route, the abundance of large mature hilsa and high GSI values in August (just before a drop in GSI in September and October) suggests that this is when brood mature fish are migrating upstream. In September, large fish are likely to be spent and migrating downstream after spawning. The high concentration of small fish in this area in October indicates that it is a nursery ground for hilsa. During March and April, there is also a large number of small hilsa in the area, probably linked to secondary spawning activities in freshwater in February (as suggested by Bladon et al. 2019).

Table 7. Monthly GSI of female hilsa in Maubin

	MAUBIN	
	N	GSI, FEMALES
Nov 2017	5	4.4
Dec 2017	5	8.3
Jan 2018	5	5.4
Feb 2018	8	3.8
Mar 2018	4	2.9
Apr 2018	3	4.9
May 2018	2	0.2
Jun 2018	0	–
Jul 2018	2	8.1
Aug 2018	7	11.2
Sep 2018	3	3
Oct 2018	7	2.8
Nov 2018	4	9.1

Figure 5. Monthly GSI of female hilsa in Maubin



3.1.3 Freshwater areas

In Danuphyu, the total length of hilsa varied from 4.4 to 53.5cm. Mature hilsa were especially abundant in June (70% of the population; see Table 8), while the largest fish were found in January–February, when 41–46% of the sampled population were at least 40cm long (Figure 6). Immature hilsa were especially abundant from August to December and from March to May (72–96% of the sampled population; see Table 8), while the smaller fish were dominant in April–May and October–November 2018, when 76–92% of the sampled population were less than 20cm long (Figure 6). GSI female values peaked in April, dropping in May and June; and then peaked again in July, before dropping in August to October (Table 10 and Figure 7).

In Hinthada, sampled hilsa ranged from 3.5cm to 49cm in total length. Mature hilsa dominated in June–July and September (64–92% of the sampled population; see Table 9) and the largest fish were also found during this period (24–30% of the sampled population were at least 40cm long; Figure 10). Immature hilsa dominated from October to May (85–100% of the population, Table 9) and smaller hilsa of less than 20cm in length were prevalent from February to May and in October (51–95% of the population, Figure 6). GSI of female hilsa were highest in March–April, dropping in May; then peaking again before dropping in August and September (Table 10 and Figure 7).

Spawning activities in September are confirmed by the abundance of immature hilsa in the area in October, when recently born fish were becoming visible. This is supported by findings from Bladon et al. (2019), which concluded that a major spawning season took place in September in this area. Large mature fish were sampled in freshwater areas in June–July and September. In July, the presence of these large fish was accompanied by high GSI values, so they were likely in the area for spawning or migrating further upstream for spawning. Conversely, in September low GSI values suggest that large fish were likely spent, having just released their eggs. Another spawning season seems to be happening in winter, around February, as we saw an abundance of small hilsa in the area from March to May.

Table 8. Monthly data on minimum and maximum total length and maturity of hilsa, Danuphyu

DANUPHYU	N	MIN TL	MAX TL	% MATURE HILSA	% IMMATURE HILSA
Nov 2017	70	17	49.5	24	76
Dec 2017	74	16.5	49.5	18	82
Jan 2018	69	16	50	48	52
Feb 2018	100	11	53.5	51	49
Mar 2018	100	8.4	50.5	22	78
Apr 2018	100	6.2	44.6	10	90
May 2018	100	4.4	41.5	4	96
Jun 2018	50	29.5	44	70	30
Jul 2018	50	28.5	43.5	50	50
Aug 2018	50	23.7	45.4	28	72
Sep 2018	72	26	41.5	19	81
Oct 2018	72	8.5	48.4	13	87
Nov 2018	103	8.5	51	9	91

Table 9. Monthly data on minimum and maximum total length and maturity of hilsa, Hinthada

HINTHADA	N	MIN TL	MAX TL	% MATURE HILSA	% IMMATURE HILSA
Nov 2017	37	20	46	16	84
Dec 2017	53	15.5	46	13	87
Jan 2018	53	19.6	49	11	89
Feb 2018	90	14.2	48.7	7	93
Mar 2018	100	7	47	4	96
Apr 2018	100	7.7	44	13	87
May 2018	85	3.5	46.5	15	85
Jun 2018	50	31.2	48.5	92	8
Jul 2018	50	27.5	45	72	28
Aug 2018	50	29.2	39	46	54
Sep 2018	50	30.5	43.5	64	36
Oct 2018	50	8.5	42	4	96
Nov 2018	100	11.5	31	0	100

Figure 6. Percentage of hilsa by size class, month and township in freshwater areas in Danuphyu and Hinthada

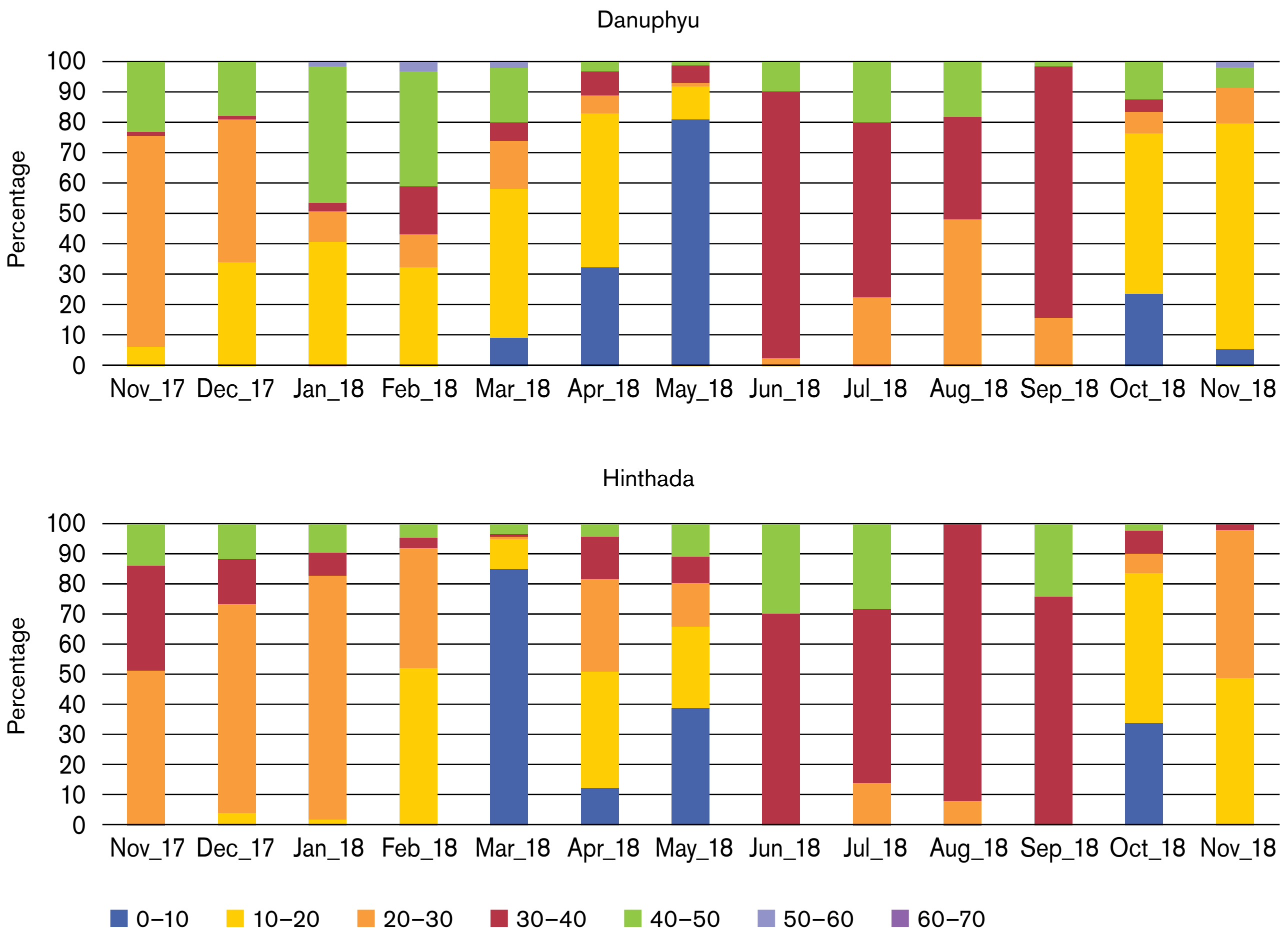
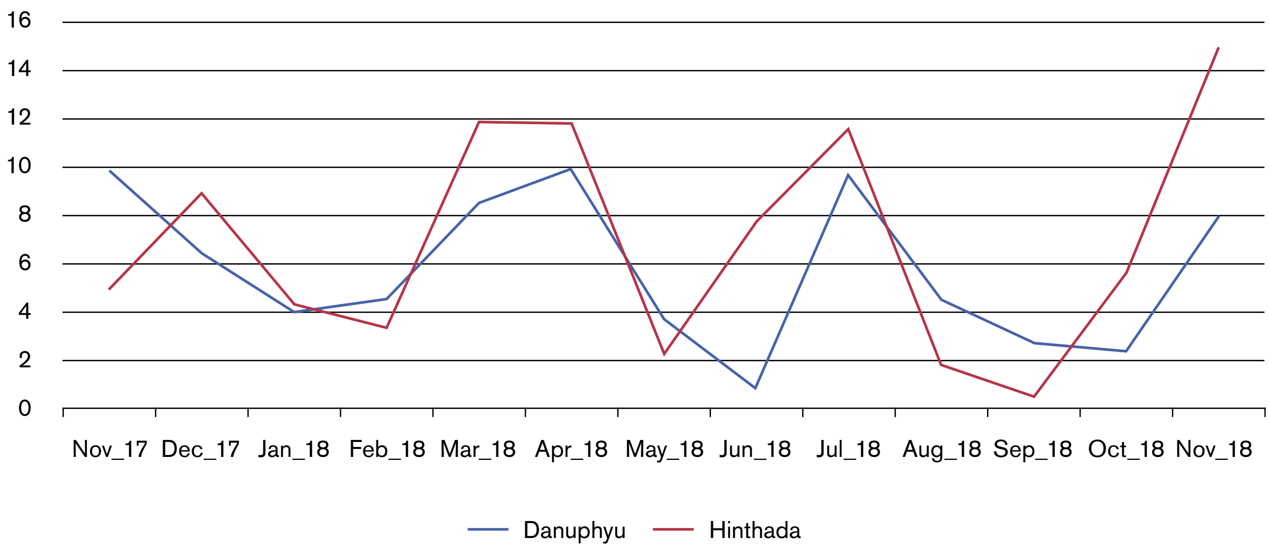


Table 10. Monthly GSI of female hilsa in Danuphyu and Hinthada

	DANUPHYU		HINTHADA	
	N	GSI, FEMALES	N	GSI, FEMALES
Nov 2017	10	9.9	5	4.8
Dec 2017	18	6.4	6	8.9
Jan 2018	13	4.0	14	4.3
Feb 2018	6	4.5	10	3.3
Mar 2018	5	8.5	3	11.9
Apr 2018	6	9.9	3	11.8
May 2018	7	3.7	3	2.2
Jun 2018	1	0.8	3	7.7
Jul 2018	3	9.7	4	11.6
Aug 2018	7	4.5	8	1.8
Sep 2018	8	2.7	4	0.5
Oct 2018	5	2.3	4	5.5
Nov 2018	5	8.0	3	15.0

Figure 7. Monthly GSI of female hilsa in Danuphyu and Hinthada



3.1.4 Summary of Ayeyarwady route

Table 11. Summary of main results of the length–frequency and maturity analysis, Ayeyarwady route

	SALINE AREAS			BRACKISH AREAS	FRESHWATER AREAS	
TOWNSHIP	LABUTTA	MAWLAMYINEGYUN	PYAPON	MAUBIN	DANUPHYU	HINTHADA
Abundance of mature hilsa (>55%)	May–Aug Oct–Dec	Mar–Nov	All year	Jan–Feb Jun–Sep	June	Jun–July September
Abundance of largest hilsa (>40cm)	Jun–Aug Oct–Dec	Mar–Jun Aug–Nov	Apr–Jul Oct–Nov	Jan–Feb Aug–Sep	–	–
Drop in GSI	Jun–Sep	Aug–Oct	Sep–Oct	Sep–Oct	May–Jun Aug–Oct	May Aug–Sep
Abundance of immature hilsa (>55%)	Jan March September	January	–	Oct–Nov Mar–May	Aug–Dec Mar–May	Oct–May
Abundance of smallest hilsa (<20cm)	–	Dec–Jan	–	Mar–Apr October	March May October	March May October

In the Ayeyarwady route, the main season of hilsa migration is in July and August, when mature hilsa start migrating upstream from saline areas. Shortly afterwards, they reach brackish and freshwater areas, where they spawn mainly in August and September. Once they release their eggs and become spent, they start downstream migration, crossing brackish areas on their way to the sea in September, and finally reaching marine areas in October. Young hilsa born in freshwater in September stay in freshwater and brackish nursery grounds during the next few months for further maturation and growth, before starting their journey to the sea.

3.2 Pathein route

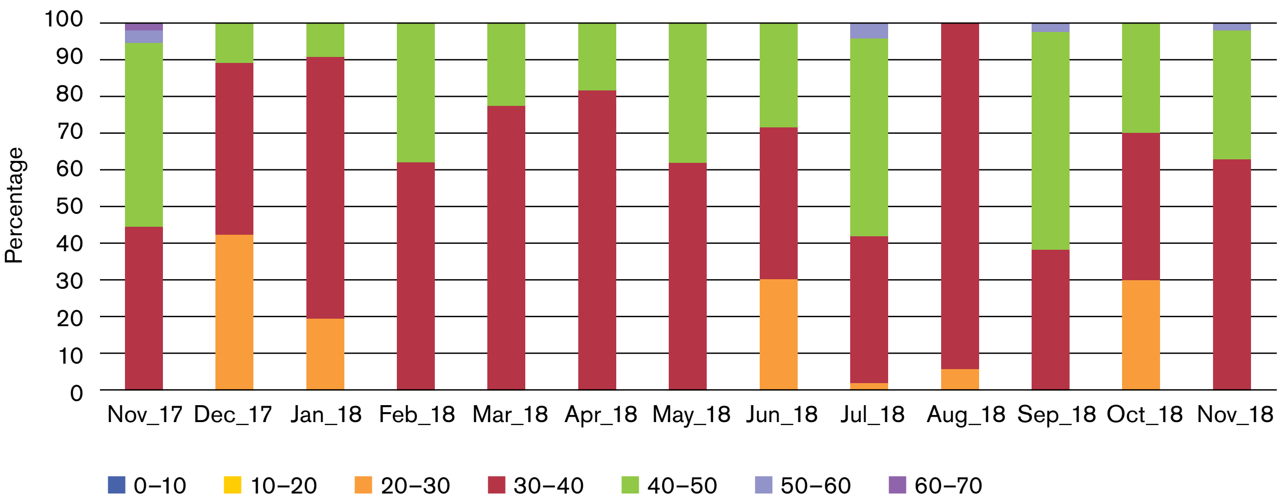
3.2.1 Saline areas

In Hainggyi, sampled hilsa ranged from 24.2cm to 61cm long. Mature fish were dominant from February to July, and in September and November, representing 66–100% of the sampled population (Table 12). The largest fish were found in July, September and November, when 55–62% of the sampled population were longer than 40cm (Figure 8). Immature fish were abundant in December–January, August and October (62–68% of the population; see Table 12), while smaller fish were sampled in December, June and October (Figure 8). Female GSI values peaked in February, dropping and remaining low from March to June; they peaked again in September, before dropping in October and remaining low until January (Table 13 and Figure 9).

Table 12. Monthly data on minimum and maximum total length and maturity of hilsa, Hainggyi

HAINGGYI	N	MIN TL	MAX TL	% MATURE FISH	% IMMATURE FISH
Nov 2017	56	30.5	61	73	27
Dec 2017	47	25	47	32	68
Jan 2018	66	25.5	45.5	38	62
Feb 2018	101	34.1	49.2	96	4
Mar 2018	103	33.7	47	97	3
Apr 2018	100	31.5	46.8	93	7
May 2018	100	35.5	48	100	0
Jun 2018	50	24.2	42.7	66	34
Jul 2018	50	28	53.5	90	10
Aug 2018	50	28	39	36	64
Sep 2018	81	32.8	51.6	96	4
Oct 2018	100	27.5	48.2	36	64
Nov 2018	100	34	51	99	1

Figure 8. Percentage of hilsa by size class, month and township in saline areas in Hainggyi

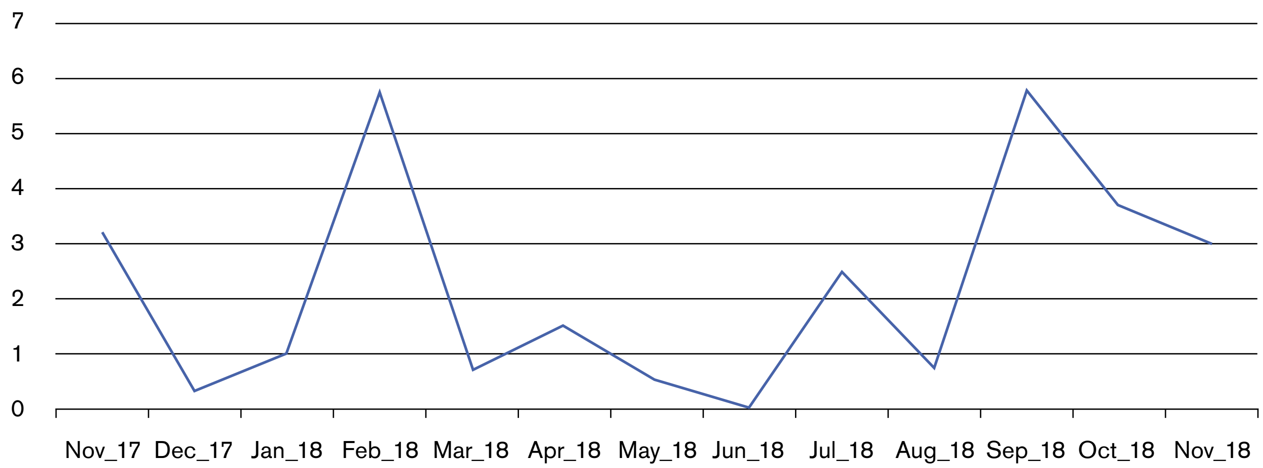


Like in the Ayeyarwady route, mature hilsa in saline areas of the Pathein route are most abundant in summer (June–August) and in October–November. We found that the largest fish were more abundant in July and September. The abundance of the largest mature hilsa in July, followed by a drop in GSI in August, suggests that these fish are likely brood mature fish that have started migrating upstream towards the spawning areas. In September, these large fish may be spent hilsa returning to marine areas just after spawning in freshwater. In December and January, the abundance of immature hilsa may indicate downstream migration during this period, as hilsa juveniles reach marine areas for further maturation.

Table 13. Monthly GSI of female hilsa in Hainggyi

	HAINGGYI	
	N	GSI, FEMALES
Nov 2017	3	3.2
Dec 2017	2	0.3
Jan 2018	3	1
Feb 2018	1	5.8
Mar 2018	1	0.7
Apr 2018	1	1.5
May 2018	1	0.5
Jun 2018	0	–
Jul 2018	1	2.5
Aug 2018	7	0.7
Sep 2018	4	5.8
Oct 2018	2	3.7
Nov 2018	5	3

Figure 9. Monthly GSI of female hilsa in Hainggyi



3.2.2 Brackish areas

In Ngapudaw, the total length of hilsa varied between 24.5 and 63.2cm. Mature hilsa dominated throughout the year (82–100% of the sampled population), except in November 2018, when immature fish represented 97% of the sample (Table 14). The largest fish were found in December–January and June–July, when fish longer than 40cm represented 80–100% of the population (Figure 10). The values of GSI of female hilsa were highest in February, April, June, November and December, and lowest in July and October (Table 16 and Figure 11).

In Pathein township, sampled hilsa ranged from 20.4cm to 63.8cm in total length. Mature hilsa dominated all year around (53–100%), except in January, when 96% of the sampled population were immature (Table 15). The largest fish were found in July and August, when 78% and 100% of the sampled population were 40cm or longer, respectively (Figure 10). Female GSI peaked in June, before dropping in July–September; and peaked again in November–December, before dropping in January (Table 16 and Figure 11).

In the Pathein route, the largest mature hilsa in brackish waters were found in the summer months (June–August). The drop in GSI values in July in both townships suggest that it is during July when brood mature fish cross this area towards upstream freshwaters. Immature hilsa are abundant in January in Pathein township, indicating downstream migration of juveniles from nursing areas during this period.

Table 14. Monthly data on minimum and maximum total length and maturity of hilsa, Ngapudaw

NGAPUDAW	N	MIN TL	MAX TL	% MATURE HILSA	% IMMATURE HILSA
Nov 2017	54	30.1	49.5	94	6
Dec 2017	68	24.5	52.2	90	10
Jan 2018	66	40.3	52.5	100	0
Feb 2018	77	30.5	53.2	97	3
Mar 2018	101	34.5	54	100	0
Apr 2018	98	31.6	49	96	4
May 2018	81	33	55	91	9
Jun 2018	76	37.8	63.2	100	0
Jul 2018	50	30	58	92	8
Aug 2018	50	28.8	43	82	18
Sep 2018	50	29.7	45.2	82	18
Oct 2018	99	30.5	54.7	89	11
Nov 2018	100	28.2	44.5	3	97

Table 15. Monthly data on minimum and maximum total length and maturity of hilsa, Pathein

PATHEIN	N	MIN TL	MAX TL	% MATURE HILSA	% IMMATURE HILSA
Nov 2017	53	30.5	50.8	75	25
Dec 2017	78	20.4	49.5	53	47
Jan 2018	55	24	46.5	4	96
Feb 2018	101	24	53.3	79	21
Mar 2018	106	22.5	49.5	74	26
Apr 2018	107	22.5	49.5	75	25
May 2018	107	28.5	55	94	6
Jun 2018	108	32	52.4	96	4
Jul 2018	50	37	54.5	100	0
Aug 2018	50	40.5	47	100	0
Sep 2018	64	31	63.8	80	20
Oct 2018	88	26.2	49.3	65	35
Nov 2018	108	25.2	52.5	62	38

Figure 10. Percentage of hilsa by size class, month and township in brackish areas in Ngapudaw and Pathein

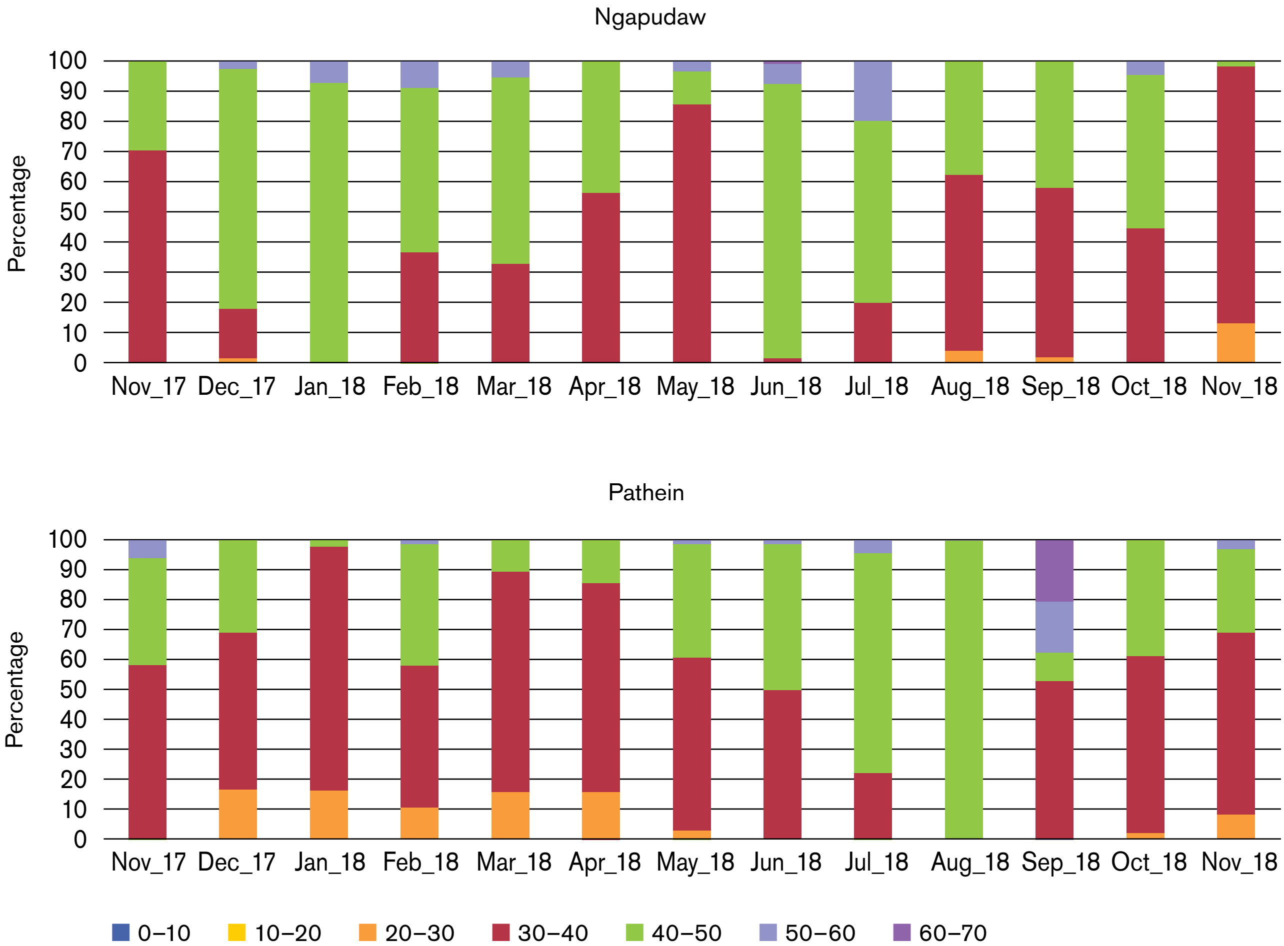
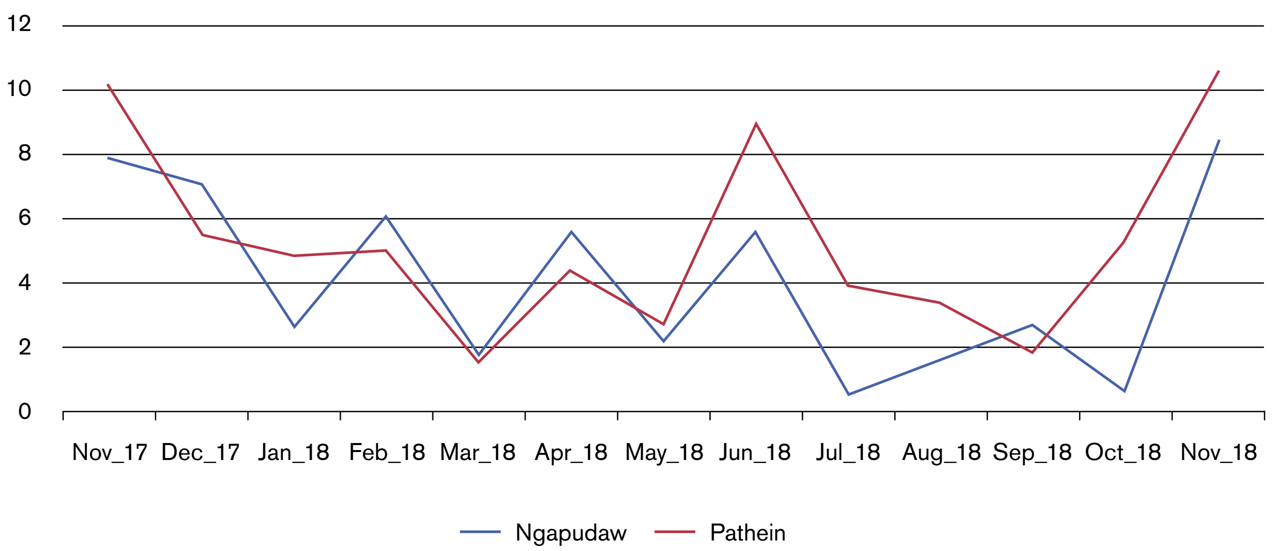


Table 16. Monthly GSI of female hilsa in Ngapudaw and Pathein

	NGAPUDAW		PATHEIN	
	N	GSI, FEMALES	N	GSI, FEMALES
Nov 2017	1	7.9	3	10.2
Dec 2017	5	7.1	4	5.5
Jan 2018	5	2.6	3	4.8
Feb 2018	6	6.1	7	5.0
Mar 2018	5	1.7	3	1.5
Apr 2018	5	5.6	3	4.4
May 2018	3	2.2	3	2.7
Jun 2018	3	5.6	6	9.0
Jul 2018	5	0.5	3	3.9
Aug 2018	8	1.6	8	3.4
Sep 2018	3	2.7	8	1.8
Oct 2018	3	0.6	5	5.3
Nov 2018	3	8.5	1	10.6

Figure 11. Monthly GSI of female hilsa in Ngapudaw and Pathein



3.2.3 Freshwater areas

See results for Hinthada in Section 3.1.3.

3.2.4 Summary of Pathein route

Table 17. Summary of main results of the length–frequency and maturity analysis, Pathein route

	SALINE AREAS	BRACKISH AREAS		FRESHWATER AREAS
TOWNSHIP	HAINGGYI	NGAPUDAW	PATHEIN	HINTHADA
Abundance of mature hilsa (>55%)	Feb–July September November	May–July	Feb–Nov	Jun–July September
Abundance of largest hilsa (>40cm)	July September	Dec–March Jun–July	Jul–Aug	–
Drop in GSI	March–June Oct–Jan	July October	July–Sep January	May Aug–Sep
Abundance of immature hilsa (>55%)	Dec–Jan August October	–	January	Oct–May
Abundance of smallest hilsa (<20cm)	–	–	–	March May October

In the Pathein route, the main season of hilsa migration takes place in July, when mature hilsa start migrating upstream from marine waters. Shortly afterwards, they will reach brackish and freshwater areas, where they spawn mainly in August and September. Once they release their eggs and become spent they start downstream migration, reaching marine areas as spent fish in September. Young hilsa born in freshwater in September stay in freshwater and brackish nursery grounds until December–January, before crossing brackish areas in January on their way down to the sea, where they arrive during the same period.

4

Recommended policy responses

Hilsa fish stocks in Myanmar are under pressure due to overfishing and habitat degradation. The migratory nature of this species makes successful reproduction of the stock dependent on the health and connectivity of the different habitats – marine, brackish, freshwater – that the hilsa encounters on their way to and from spawning areas. Effective policy interventions are therefore necessary to ensure restoration of the hilsa population and the long-term sustainability of this fishery.

Based on our results on the seasonal migratory route of hilsa, we suggest several policy interventions in each of the three ecological zones in the Ayeyarwady Delta:

- In the marine environment, we recommend a ban on catches of adult hilsa fish in July and August, when the largest brood mature fish are found in both the Ayeyarwady and Pathein route areas.
- In brackish waters, we recommend the protection of juveniles in the Maubin–Ayeyarwady route brackish area. We recommend a total ban on fishing in this nursery ground during October. We also suggest a similar measure to protect juveniles during March and April due to the abundance of juveniles in the area, likely linked to a secondary spawning season in freshwater in February.
- In freshwater areas, as suggested by Bladon et al. (2019), we recommend the special protection of spawning and nursery areas in September and October, when the main spawning season takes place.
- In all areas and at all times of the year, we suggest the introduction of a minimum landing size for hilsa so the catch of smaller immature fish is banned. This should increase the reproductive potential of the stock. This minimum size should be set at around 34cm in total length. According to our estimation on length at maturity, hilsa below this length can be considered immature.
- The introduction of the ban regulations suggested above implies reductions in income and food from fishing for fisher communities. In order to support their livelihoods during periods of fishery closure and increased compliance, compensation for lost income should be provided. The design of an incentive management scheme for Myanmar that compensates fishers in times of fishery closures, delivering both environmental and social sustainability, is the main objective of the Darwin Initiative-funded project this study is part of.
- Alternative policy options that do not include a total ban on fishing should be explored, to avoid imposing a disproportionate burden on fishers. For example, in marine areas in summer, when large hilsa fish are abundant and represent an important income source for fishers, the introduction of a fishing ban is likely to encounter strong opposition. Instead, introducing a limit on total catches or restrictions on the fishing access in the marine area during those months may be more appropriate. This scheme could be combined with the designation of a no-take marine area[4] that protects marine brood mature fish to ensure reproduction is successful. The country capacity in terms of monitoring and enforcement of this type of regulation needs to be analysed, as well as the feasibility and potential benefits of a co-management scheme.

[4] A marine protected area where no fishing, mining, drilling, or other extractive activities are allowed.

5

Summary and conclusions

Our sampled data appears to support the idea of Hossain et al. (2016) that some hilsa stocks permanently reside in marine areas (for example, due to observed spawning activity in saline waters in Mawlamyinegyun in December–January). A general pattern of fish migration between saline, brackish and freshwater areas can also be identified based on the available length–frequency and maturity data.

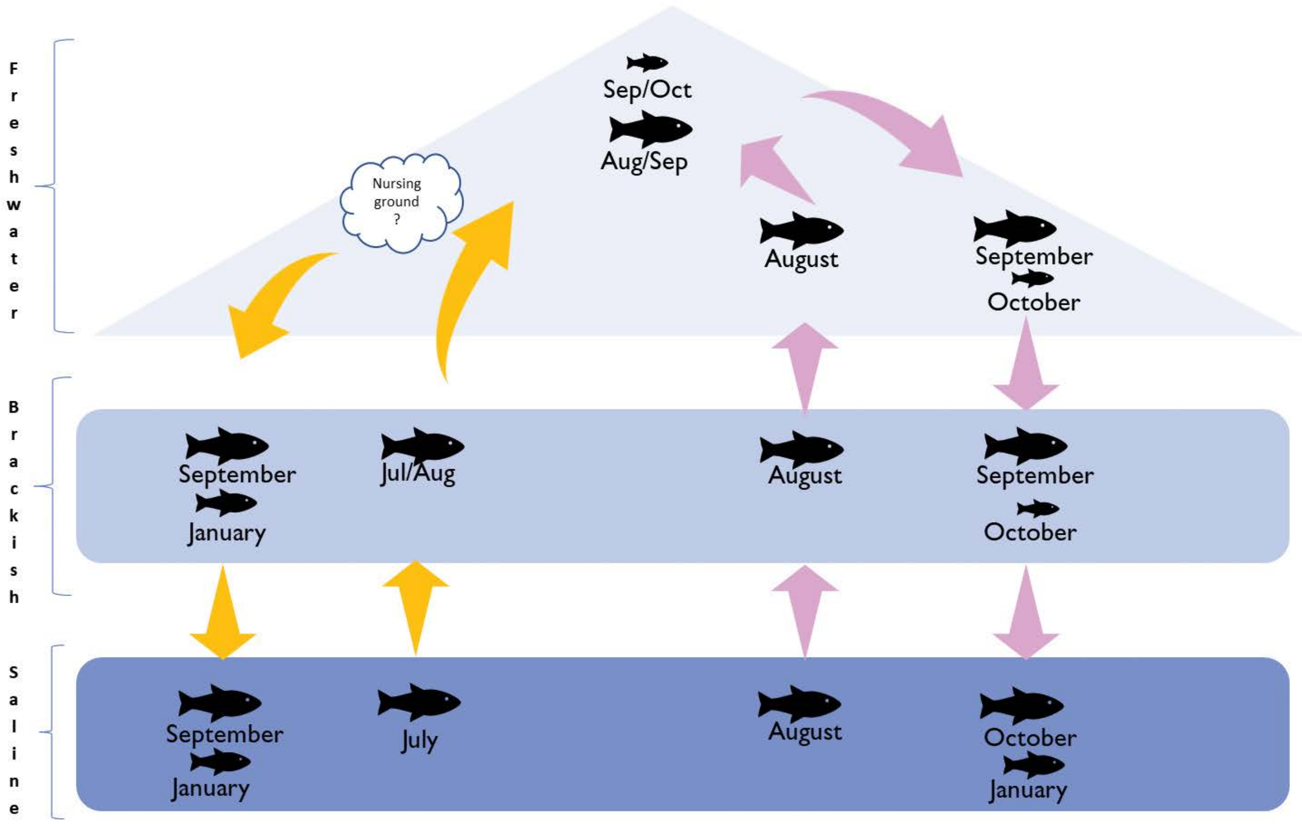
Based on the results from the previous section, we can map the movements of hilsa by migratory route throughout the year, assuming a main migratory season for spawning during the southwest monsoon season (see Figure 12). In the Pathein route, large brood mature hilsa start migrating upstream from marine areas in July. They quickly move through brackish areas during July and August and reach freshwater in August, where they spawn mainly in September. After spawning, the spent large fish migrate downstream, back to the sea. Small hilsa are born and nursed in freshwater areas in September and October, before they start downstream migration towards the marine environment. According to our results, these small juveniles do not reach brackish areas until December, which indicates that between October and December they remain in freshwater, but outside of our sample sites. After having reached brackish areas in December, they continue their journey towards the sea, where they arrive in January.

Similarly, in the Ayeyarwady route, hilsa start migrating upstream in August, and quickly advance through brackish waters to freshwater areas, where they spawn in September. Large spent hilsa then start migrating downstream, reaching marine areas in October. In October, small hilsa are nursed in freshwater areas, with another nursery ground in brackish waters, on their journey to the sea. They reach marine areas in December.

There are two main spawning seasons for hilsa. The one referred to above corresponds to the southwest monsoon. In winter, another smaller hilsa migration for spawning takes place, involving smaller fish. Our results show that hilsa spawns in freshwater in February, nursing during March and April in both freshwater and brackish water areas, mainly in the Ayeyarwady route. As mentioned in the introduction, the southwest monsoon has a great influence in the spawning and migratory seasonal patterns of hilsa, by modifying the environmental conditions that support the reproductive cycle, as well as the general wellbeing and sustainability of this species. As well as other factors such as habitat degradation, climate change is likely to impact how hilsa reproduces and migrates. Therefore, any management mechanism should be designed in a way that accounts for this uncertainty and is flexible enough to adapt to potential climate-induced changes in the stock.

According to a study on climate trends in Myanmar by Aung et al. (2017), climate change is already changing rainfall and temperature patterns in the country. Monsoon season has shown a decrease in rainfall – and the rainy season is now shorter than in previous decades. In terms of temperature, average annual temperatures increased by 0.5°C in the period 1981–2010, compared to previous decades. This reduction in rainfall can pose an obstacle to hilsa migration as water current and depth is likely to decrease. The rising temperature may also affect the productivity of the stocks.

Figure 12. Main seasonal hilsa migration in Myanmar by ecological area through Pathein route (orange) and Ayeyarwady route (lilac)



It should be noted that the data-collection method used in our study – where sampled fish were collected from catches on landing sites – may introduce bias. The use of different fishing gears and mesh sizes by area and season may have influenced the size of fish sampled in this study. Therefore, it may not be accurately representative of the fish population (Froese 2006). In addition, the collection of fish samples extended over a period of 13 months, covering two November months, in 2017 and 2018. Differences in results for these months suggest great variability from year to year in terms of seasonal distribution of hilsa in the delta – for example, in the abundance of mature hilsa in saline areas. On the other hand, Baran et al. (2015), based on fishers' perceptions, state that annual migration patterns and breeding sites do not essentially vary from year to year. Therefore, more research on length–frequency by area and month across several years is necessary in order to assess to what extent this variability may affect policy interventions.

A project funded by the Australian Centre for International Agricultural Research (ACIAR) in collaboration with Charles Sturt University and Adelaide University in Australia is currently carrying out an otolith chemical analysis on samples of hilsa collected in the three ecological zones of the delta: freshwater, brackish and marine areas. This will hopefully expand the knowledge on migratory behaviour of hilsa in Myanmar by complementing the results of our study.

Related reading

Bladon, A, Myint, KT, Ei, T, Khine, M, Aye, PT, Thwe, TL, Leemans, K, Soe, KM, Akester, M, Merayo, E and Mohammed, E Y (2019) Spawning seasonality of hilsa (*Tenualosa ilisha*) in Myanmar's Ayeyarwady Delta. IIED, London. https://pubs.iied.org/16661IIED

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Hilsa shad is one of the most important fisheries in Myanmar, providing livelihoods and nutrition to thousands of vulnerable communities. However, overfishing and habitat destruction are putting at risk the sustainability of the fishery. This study aims to expand the knowledge of the ecology of the hilsa fishery, by discussing the seasonality and preferred routes of this migratory fish. This information will help inform policy interventions as to where and when fishery closures are most cost efficient, in order to maximise the reproductivity of the stock and ensure its long-term sustainability.

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