Common Anchor Types for Ocean Farming

1. Fluke

Fluke anchors are *light-weight type* (LWT) *drag-embedment anchors* with a hinged *stock* that allows the anchor to self-right. The sharp *flukes* easily dig into sand and mud from either side of the *shank,* but are not reliable in hard clay or rocky bottoms where the fluke can't penetrate. Although the hing is prone to corrosion and jamming, fluke anchors have an excellent holding power to size ratio: the Fortress brand fluke anchor has exceeded 200:1 holding power to weight ratio at 5:1 scope. However, holding power varies widely in different bottom types and conditions. And because there may be dramatic differences in performance between anchors of the same style that are manufactured by different companies and with different materials, we conservatively estimate an average holding power to size ratio of 25:1. The materials––such as hi-tensile or standard steel––and the sharpness of the fluke, among other properties, influence the ease of setting and holding power.

Fluke anchors are directional anchors that rely on horizontal pull (in our case, the pull from the longline), they work best when oriented parallel to current, and require a 5:1 to 7:1 scope to depth at MHW. As a farmer, you will need to "set", not just drop, a fluke anchor; but they are generally easy to set and retrieve and are a great anchor for most ocean farm applications.

Fluke Anchor[1]

[1] Image Source: Hamilton Marine (2020) Anchor Danforth Standard. Retrieved online 9/9/2020 https://shop.hamiltonmarine.com/products/anchor-danforth-standard-43553.html

Average holding power: 25:1
Minimum scope required: 5:1
Best bottom type: sand and mud
Pros: self-righting, easy to set and retrieve in most applications
Cons: hinged stock is prone to corrosion and jamming; may lose holding power if direction of pull changes
Tip: use chain to improve angle of anchor line and prevent line from sitting on bottom
Price Range per Pound: $1.50 - $12.50
Average Price per Pound: $3.34
Brand names: Danforth, Fortress, Lewmar, Washington Chain & Supply

2. Rigid Fluke

Unlike fluke anchors, these anchors can not be simply dropped off the bow to eventually catch. They need to be lowered and oriented into the anticipated direction of pull. One placed on the bottom they are quick to dig and offer high holding-power ratios. The line of anchors from TendOcean™ comes in eight sizes ranging from 90 to 5,600 pounds. It's long, double shanks and wide flukes at an optimal 36˚ makes for reliable holding in both sand and mud. They come in bare steel, coated with coal tar epoxy and hot-dip Galvanized. Other manufacturers of this type include Jekco (Australia) and Vryhof (The Netherlands).

TendOcean Rigid Fluke

Average holding power: 30:1

Minimum scope required: 4:1 (with chain)

Best bottom type: mud, sand & gravel

Pros: quick setting, all welded steel

Cons: must be lower to the seabed and oriented for best performance.

Tip: lower the anchor from the rear retrieval point or the lower cross brace at the balance point

Price Range per Pound: $2.15 - $4.50

Average Price per Pound: $3.25

Brand names: TendOcean, Stingray, Vryhof

3. Plow and Wing

Plow and wing anchors are *stockless drag embedment anchors.* Both have a spade-shaped *fluke* that is designed to furrow (like a plow[2]) until it embeds.

The original plow-style anchor (called the CQR, or “secure”) has an articulating, multi-directional *shank* that rotates approximately 70° the left and right. This feature was developed to allow the anchor to rotate onto the sharp edge of its fluke and dig into sediment and then right itself as it

[2] i.e. a double-bladed ploughshare

embeds. Some proponents of the articulating plow claim that the multi-directional shank allows the anchor to be more responsive to changes in tides and currents, and suggest that it can hold hundreds of times more than its weight in the right conditions.[3] Others suggest that it does not reliably set[4] and it breaks free more often than its successor, the Delta-style wing anchor (i.e. the non-articulating plow).[5]

We suggest avoiding the articulating plow for ocean farming applications.

Similar to fluke anchors, plow and wing anchors rely on horizontal pull from a single direction and require a 5:1 to 7:1 scope to depth at MHW in order to maintain optimal holding power. In one test, the non-articulating plow, or Delta-style wing anchor, exhibited an average holding power of 110:1 in sandy substrate.[6] But as with most anchors, holding power varies significantly in different bottom types and conditions. Given this variability, we conservatively estimate an average holding power to size ratio of 25:1 in sand and mud. These anchors tend to plow rather than set in silt and soft sediments and don't easily penetrate compacted sediments and hard clay. Otherwise, plow and wing anchors are fairly easy to set and retrieve. Lower the anchor slowly or attach a crown line (sometimes called a trip, tow, or retrieval line) to the base of the stock to guide the anchor into position.

Note that although some small-scale ocean farmers have used plow and wing anchors for single-line arrays, these anchors are traditionally used for recreational boating and are not typically used for ocean farming.

Articulating Plow[7] *Wing (Non-Articulating Plow)*[8]

[3] Chapman, Charles F., M.E. (1968) Piloting, Seamanship, and Small Boat Handling. The Hearst Corporation. Stratford Press, Inc. NY. 1969/70 Edition. p 98-100.
[4] citing *Voile*—Smith, Peter (1970-2020) Anchors and Anchoring. petersmith.net.nz. Retrieved online: https://www.petersmith.net.nz/boat-anchors/independent-performance-testing.php
[5] Springer, Bill (2006) Holding Power. Sailmagazine.com. October 2006 Retrieved online: https://newcontent.westmarine.com/content/documents/pdfs/WestAdvisor/2006-Anchor-Tests.pdf
[6] Springer, Bill (2006) Holding Power. Sailmagazine.com. October 2006 Retrieved online: https://newcontent.westmarine.com/content/documents/pdfs/WestAdvisor/2006-Anchor-Tests.pdf
[7] Image Source: West Marine (2020) Lewmar CQR Anchors. Retrieved online 9/9/2020 https://www.westmarine.com/buy/lewmar--cqr-anchors--P005_153_002_005
[8] Image Source: West Marine (2020) Lewmar Galvanized Delta Fast-Set Anchor. Retrieved online 9/9/2020 https://www.westmarine.com/buy/lewmar--galvanized-delta-fast-set-anchor--P06715593?recordNum=1

Average holding power: 25:1
Minimum scope required: 5:1
Best bottom type: sand and stiff mud
Pros: relatively easy to set and retrieve
Cons: expensive; better for yachting than commercial applications; can lose holding power if sudden shift in direction of pull; may furrow and be difficult to set in some bottom types
Tip: use a crown or trip line to set and retrieve these anchors
Price Range per Pound: $7.73 - $25.14 (articulating plow); $3.91 - $8.81 (non-articulating plow/wing)
Average Price per Pound: $18.68 (articulating plow); $6.99 (non-articulating plow/wing)
Brand name: Lewmar (for both Delta wing/non-articulating plow and CQR articulating plow)
Note: Lewmar recommends its products for recreational use and recommends further consultation and approval by Lewmar engineering and management before use in commercial applications.[9]

4. Claw

Claw anchors are *drag embedment anchors* with a fixed *shank* and scoop-shaped *fluke.* The curved *wing tips* on the fluke help it roll into the upright position when setting. In independent tests in sand and mud, breakout force varied widely: and holding power to weight ratios from 8:1 to over 100:1 were observed at 5:1 and 7:1 scope.[10,11] Given this variability, we conservatively estimate a holding power of 25:1 in sand and mud.

Claw anchors are fairly easy to set and retrieve, and are a go-to anchor in many commercial applications––such as the salmon set-netting in Alaska––because of their availability and

[9] See Note below Product Description: https://www.defender.com/product.jsp?id=3298720#description
[10] Springer, Bill (2006) Holding Power. Sailmagazine.com. October 2006 Retrieved online: https://newcontent.westmarine.com/content/documents/pdfs/WestAdvisor/2006-Anchor-Tests.pdf
[11] Smith, Peter (1970-2020) Anchors and Anchoring. petersmith.net.nz. Retrieved online: https://www.petersmith.net.nz/boat-anchors/independent-performance-testing.php

durability. But the curved fluke doesn't penetrate more compacted substrates as easily as sharper flukes on other drag embedment anchors. To improve penetration and holding power, ensure that the anchor has plenty of scope (minimum of 5:1) and has ample horizontal pull. Use an anchor chain to improve the horizontal pull. Lower the anchor slowly or attach a crown line (sometimes called a trip, tow, or retrieval line) to the base of the stock to guide the anchor into position.

Claw Anchor[12]

Average holding power: 25:1
Minimum scope required: 5:1
Best bottom type: sand and mud
Pros: durable; relatively easy to set and retrieve
Cons: does not reliably set in compacted sediments; can lose holding power if sudden shift in direction of pull
Tip: use a crown or trip line to help set and retrieve
Price Range per Pound: $2.88 - $4.55
Average Price per Pound: $3.94
Brand name: Bruce

5. Mushroom

Mushroom anchors are cast iron embedment anchors shaped like an inverted mushroom. The curved *cap* (or *bell*) and weight of the anchor help it to settle into the sediment and generate suction. Mushroom anchors work best in soft sediments, such as silt, soft mud, and loose sand. Lower the mushroom into the water in an upright position. Then allow the anchor to settle into the sediment for a day or two before using. Once embedded, the average holding power is about 4:1––but over time, as sediment accumulates on top of the dish, holding power may increase up to 10:1. If a mushroom anchor is on a hard bottom or doesn't settle, it's holding power is only as good as it's weight. A 3:1 scope to depth at MHW is sufficient in most circumstances. When sized appropriately, mushroom anchors work well for permanent moorings where the direction

[12] Image Source: Dark Horse Marine, LLC (2020) Galvanized Claw/Bruce Style Anchor - 48 lbs. Retrieved online (9/9/2020) https://www.darkhorsemarine.com/galvanized-claw-bruce-style-anchor-48-lbs/

of pull changes––but be aware that the anchor line can wrap around the long shank as the direction of pull changes and the cap rolls on the seafloor. Use an anchor chain and a swivel to reduce the chances of line wrapping.

Mushroom Anchor[13]

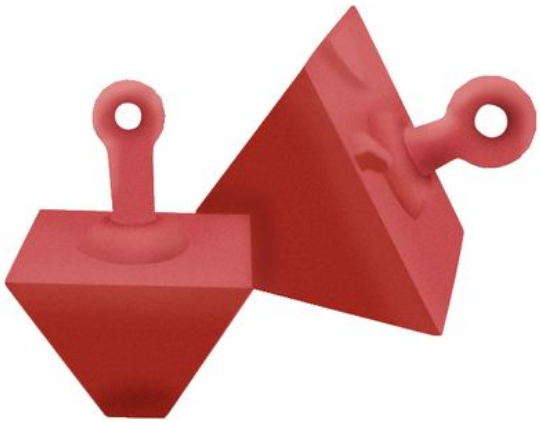
Average holding power: 4:1
Minimum scope required: 3:1
Best bottom type: silt, soft mud, unpacked sand
Pros: can handle multi-directional (360°) pull; great for permanent moorings
Cons: low weight to holding power ratio; anchor line may wrap around the shank if direction of pull changes; prone to dragging if not properly embedded
Tip: use a chain and swivel to reduce the chances of line wrapping around the shank; allow the anchor to settle for a day or two before applying tension
Price Range per Pound: $1.15 - $1.43
Average Price per Pound: $1.36
Brand name: Seachoice

6. Pyramid

Pyramid anchors are cast iron embedment anchors that are shaped like a pyramid. These anchors are essentially a redesign of the mushroom anchor. The short shank on the pyramid anchor is less prone to anchor line wrapping than mushroom anchors. Their sharp edges dig in more quickly than mushroom anchors and the sides of the pyramid provide ample surface area for suction. Pyramid anchors have a 10:1 holding power at 3:1 scope in silt, soft mud, and unpacked sand, but their holding power diminishes substantially in harder substrates. Pyramid anchors are not recommended for exposed sites.

[13] Image Source: Defender Industries, Inc (2020) Mushroom Mooring Anchor. Retrieved online 9/10/2020 https://www.defender.com/expanded.jsp?path=&id=3975451

Pyramid Anchor[14]



Average holding power: 10:1
Minimum scope required: 3:1
Best bottom type: silt, soft mud, unpacked sand
Pros: can handle multi-directional (360°) pull; good for permanent moorings in shallow water in soft sediments
Cons: prone to dragging if not properly embedded
Tip: use a chain and swivel to reduce the chances of line wrapping around the shank; allow the anchor to settle for a day or two before applying tension
Price Range per Pound: $0.74 - $5.71
Average Price per Pound: $3.99
Brand name: Dor-Mor

[14] Image Source: iBoats (2019) Seachoice Pyramid Anchor. Retrieved online 9/10/2020 https://www.iboats.com/shop/seachoice-pyramid-anchors-25-75-lb-range.html?opt=IB00299289&gclid=CjwKCAjwnef6BRAgEiwAgv8mQSuFrCG27f9XRkNdbLTlfPhmDt02KKbP1V8_J4iktUbwjjcpl8YnLxoC-oIQAvD_BwE#configurable_option=50%20lb.

7. Deadweight

Deadweight anchors are heavy objects repurposed for use as permanent moorings. Granite slabs, engine blocks, and objects that maintain their weight in water have been used as deadweight anchors; but steel railroad wheels (weighing between 235 and 480 lbs) are among the most common objects used for this purpose. Stacks of two to four railroad wheels, bolted together and attached to a chain, have been used to anchor scientific instruments, secure deep water moorings, and provide permanent moorings in boat harbors. Railroad wheels and other deadweight anchors are relatively inexpensive (about $0.40 - $1.00/lb) and are often available at metal salvage or scrap yards or quarries. But the holding power of deadweight anchors is only equal to their weight (1:1 holding power to weight ratio) with a small amount of additional holding power generated by the friction between the anchor and the seafloor. In other words, deadweight anchors are cheap, but they will need to be very large to supply adequate holding power for most ocean farm needs. You will also likely need additional infrastructure, such as a barge and crane or A-frame, to transport the size and quality of deadweight anchors you require. Retrieving deadweight anchors is equally cumbersome.

There are some advantages to using deadweight anchors: they need relatively little scope to function properly (3:1), they can handle multi-directional (360°) pull, and they are suitable for a range of bottom types (from grass, to sediment, to rock).

If you have a stockpile of deadweight anchors and are considering using them for your farm, we strongly recommend that you consult your local harbormaster or harbor management commission and other relevant agencies to determine whether they are approved and appropriate for your site. We strongly recommend against using engine blocks and other repurposed materials that could cause environmental harm.

Deadweight - Railroad Wheel Anchor[15]

[15] Image Source: Boat Gear Direct (2020) Railway Wheel Sinker S-RWS. Retrieved online 9/10/2020. https://www.boatgeardirect.co.uk/sinkers/sinker-accessories/product/324-railway-wheel-sinker

Average holding power: 1:1
Minimum scope required: 3:1
Best bottom type: all bottom types
Pros: can handle multi-directional (360°) pull; requires relatively little scope
Cons: cumbersome to deploy and retrieve––may require additional infrastructure; anchor may slide in some sediments; ground tackle may wrap around the deadweight anchor if lines go slack and forces pull in different directions; not all harbormasters and regulatory agencies will approve deadweight anchors
Tip: the position/orientation of the anchor is not important if chain is used and chafing is not a concern; the anchor doesn't need to settle into the sediment before use, but settlement may increase holding power in some bottom types
Price Range per Pound: $0.40 - $1.00
Average Price per Pound: $0.59
Brand name: N/A

8. Concrete

Concrete anchors come in many different shapes and sizes and can be manufactured or homemade. Newer manufactured varieties include Habitat Mooring Systems ® ––specially designed concrete anchors with chambers and tunnels that shelter all sorts of marine life (from lobsters and crabs to shrimp, sea urchin, and small fin fish).

The primary advantage of concrete anchors is that the raw materials (cement, sand, gravel, and water) are relatively cheap and widely accessible. Concrete anchors can also handle multi-directional pull and, if designed and installed properly, concrete anchors can be very secure and long-lasting permanent moorings. The disadvantage is that concrete loses 40-50% of its weight in water and it's holding power is only equivalent to its submerged weight (i.e. it has a weight to holding power ratio of 1:0.5). In order to achieve roughly 1000 lbs of holding power you will need a 2000 lb concrete anchor (dry weight). Due to the size requirements, you may also need additional infrastructure, such as a barge with a crane or A-frame, to transport, hoist, and set concrete anchors on your farm. Retrieving concrete anchors is equally cumbersome.

Concrete anchors work in a range of bottom types, but not are not necessarily suitable for all ocean farm applications. Consult your local harbormaster or harbor management commission and other relevant agencies to determine whether concrete anchors are approved and appropriate for your site.

Manufactured Concrete Habitat Mooring System ® [16]

[16] Image Source: Hamilton Marine (2020) Habitat Mooring System. Retrieved online 9/11/2020. https://shop.hamiltonmarine.com/products/habitat-mooring-system-44796.html.

Average holding power: 1:0.5
Minimum scope required: 3:1
Best bottom type: all bottom types
Pros: can handle multi-directional (360°) pull; requires relatively little scope; can be homemade
Cons: cumbersome to deploy and retrieve––may require additional infrastructure; may crack or break if not handled properly; loses 40-50% of its weight in water; not all harbormasters and regulatory agencies will approve concrete anchors
Tip: the anchor doesn't need to settle into the sediment before use, but settlement may increase holding power in some bottom types
Price Range per Pound: $0.05 - $0.41
Average Price per Pound: $0.21
Brand name: Habitat Mooring System

9. Helical

Helical anchors are *embedment anchors* made up of one or more *helical blades*[17] attached to a vertical *shaft*. Helical blades vary in diameter, typically from about 4-12", and shafts vary in length (4' to 6' or more) and shape (round/cylindrical or square/cuboid) on different models. Helical anchors (sometimes called "screw anchors") designed to be screwed into the seafloor––a job that can be done by hand in shallow water, but requires divers and/or special drilling[18] equipment in deeper water. The anchors themselves are relatively cheap, but installation and removal costs may be 5-10x the cost of the anchor.

Helical anchors are used extensively in mooring fields and in ocean farming applications. They are multi-directional, require relatively little scope (2:1 is acceptable), and have phenomenal holding power when sized and installed properly. But holding power depends upon bottom type, penetration depth, and installation torque as well as number and size of blades and shaft length. Subsequently we don't supply a holding power to weight ratio as we do with other anchor types:

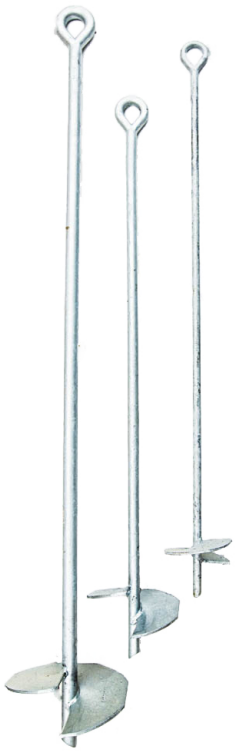
[17] Also referred to as *plates* or *disks*
[18] Usually hydraulic

it's just not an apples-to-apples comparison.[19] Rather, we encourage you to identify the holding power requirements for your arrays and consult an installer to determine appropriate sizing.

Helical anchors work best in clay-sand sediments and are often used in sensitive habitats because of their small footprint and minimal impact on the seafloor. They do not work well in loose sediments, and are not designed for use in rock/reef environments.

Helical anchors are the most affordable option for shallow water sites with sandy to stiff muddy bottoms, and are a great pick for sites where you want to maximize space for your growlines and don't have a lot of room for scope, and where installation costs are not going to break the bank.

Helical Anchors[20]



Average holding power: depends upon installation torque, blade size, shaft length; breakout force between 800 lbs and 20,800 lbs reported in marine environments
Minimum scope required: 2:1

[19] I think Beth Leonard said it well: "Comparing the holding power of a helix anchor to that of a traditional mushroom or deadweight anchor is like comparing a wood screw to a thumbtack or paperweight,"
Source: Leonard, Beth A. (n.d.) Everyday Moorings. BoatUS.com © 2020. Retrieved online 9/10/2020: https://www.boatus.com/seaworthy/magazine/2014/january/everyday-moorings.asp
[20] Image Source: Helix Mooring Systems, Inc. (2016) Helix Round Shaft Anchors. Retrieved online 9/15/2020: https://helixmooring.com/round-shaft-anchors/

Best bottom type: sand, mud, clay
Pros: can handle multi-directional (360°) pull; requires relatively little scope; may be good for sensitive habitats due to small footprint and minimal impact on bottom; low cost per unit; the anchor doesn't need to settle into the sediment before use
Cons: will require additional infrastructure to deploy and retrieve on most sites; installation costs vary depending on location, bottom type, and other factors; if the anchor fails, it fails completely
Tip: if using in softer sediments, increase the disk size; the greatest holding power is with vertical forces, but be sure to use enough scope to mitigate shock loading
Price Range: $17.92 - $167.59
Average Price per Anchor: $70.45
Brand name: Helix Mooring Systems, Inc., Eco-Mooring Systems

10. Manta Ray ®

Manta Ray anchors are lightweight *embedment anchors* designed to be driven into the earth (i.e. seafloor, for marine applications) by hydraulic or pneumatic equipment, such as underwater jackhammers. The complete anchor system consists of a hinged steel base-plate with an arrow-like taper on one side, one or more threaded rods (the shaft), and a swivel eye at the terminus of the rod. An additional steel rod, called a *drive steel*, is attached to the anchor for setting, and removed once the base-plate is driven to the proper depth.

Once at depth, special equipment is used to pull the anchor upward––which causes the base-plate to rotate outward and resist vertical force––until it is set and *proof tested* at the desired holding capacity.

Ultimate holding power for Manta Ray anchors is 40,000 lbs. But actual holding power depends upon the size of the base-plate, the depth of installation, the substrate, and other factors. The MR-SR, MR-1, and MR-2 models are recommended for marine applications; and Manta Ray reports holding powers ranging from 9,000-40,000 lbf, 8,000-40,000 lbf, and 5,000-28,000 lbf, respectively, for these three models. With each of these models weighing less than 25 lbs, their potential weight to holding power ratio is off the charts.

Manta Ray (and Stingray Model) Anchor Base-Plates[21]

[21] MacLean Power Systems https://www.macleanpower.com/product/anchors-utility/manta-ray-earth-anchor

Average holding power: depends upon size of base-plate, installation depth, substrate, and other factors; these lightweight anchors (12 - 21 lbs/each for the recommended models) have up to 40,000 lbs holding power reported in marine environments, but safe to assume 2:1 structural safety factor (i.e. maximum holding power of 20,000 lbs)
Minimum scope required: 2:1
Best bottom type: gravel, compacted sediments, sand, mud, clay
Pros: can handle multi-directional (360°) pull; requires relatively little scope; may be good for sensitive habitats due to small footprint and minimal impact on bottom; low cost per unit; the anchor doesn't need to settle into the sediment before use
Cons: considered permanent; will require additional infrastructure to deploy and retrieve on most sites; installation costs vary depending on location, bottom type, and other factors; if the anchor fails, it fails completely
Tip: if using in softer sediments, increase the size of the base-plate; the greatest holding power is with vertical forces, but be sure to use enough scope to mitigate shock loading
Average Price per Anchor and Drive Steel: $136.00
Brand name: Manta Ray ® Earth Anchor